SYLLABUS
of
Elementary Physiology
with
References
and
Laboratory Exercises.

Ulysses O. Cox.

A SYLLABUS

—OF—

Elementary Physiology

—WITH—

References and Laboratory Exercises

—BY—

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PREFACE.

The outlines and laboratory exercises here presented are the outgrowth of the work in Physiology in the author's classes, and it is at the request of several fellow teachers that they now appear in print. The work has been with pupils who have not had previous training in the other science subjects. Logically, Physiology should follow the work in Zoology, Physics and Chemistry, in a course of study, but, at present, most schools require that this study be pursued early in the course, consequently it is necessary that a little Chemistry and Physics, and Zoology and Anatomy precede the real work in hand, and this explains why the introductory chapter presents what it does. It will be found desirable to do the work indicated in this chapter and, if the students cannot be taken into the chemical laboratory to perform the experiments individually, they should be made before the class by the teacher. Whenever possible, each student should do the laboratory work for himself.

It is thought that the outlines are so general that they may be used with almost any text, but they follow more closely the works of Dr. Newell Martin than any other. The outlines are not intended to be exhaustive but rather suggestive, and the student is supposed to elaborate on the various subjects as far as the time will allow. On the other hand, some of

the subjects may be too complex for beginning classes, and in such cases they may be omitted.

The dissections and experiments should all be carefully made, so far as the apparatus and other conditions will permit, since the subject is one especially suited to laboratory methods. No effort should be spared to secure the additional apparatus and material for the work as suggested. Text-book work alone in Physiology is very unsatisfactory.

Each student should keep a neat note-book in which drawings are made and the results of all experiments and observations recorded, as well as extracts of articles read in reference books.

At the close of the pamphlet will be found a list of standard reference books on the subject, together with a few of the more common text-books now in use. To economize space, each reference work has been given a number and these numbers occur in bold faced type throughout the text, followed, usually, by the page on which the information is to be found. In case the number of the reference alone is given, the student should consult its index. It is not supposed that every school will posses all the works of reference included in the list, but every school should have some of them. Nothing can be more unsatisfactory in a subject like Physiology than to confine the student to a single text-book.

Individual members of the class should be assigned subjects for investigation, reports on which may be made either orally or in writing. Such investigations should include as much reference work as possible, as well as laboratory observation.

If this pamphlet should help some teacher to teach or some student to pursue the subject of Physiology according to modern scientific methods, it will have served its purpose. The author invites criticisms and suggestions from fellow teachers for the improvement of future editions. A few typographical errors have crept in, but none, so far discovered, are of a serious nature.

I wish here to acknowledge my obligations to Mr. Carl J. Ulrich, my assistant, who has aided in the preparation of some of the outlines and laboratory exercises, and to my wife who has assisted in reading the proof.

U. O. C.

Mankato, Minn.,
December 16, 1899.

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INTRODUCTION

INTRODUCTORY OUTLINE.

MATTER.

1a. Inorganic.
  1b. Definition.
  2b. Some studies treating of.
    1c. Inorganic chemistry.
      1d. Some elements common in animal bodies. **4**, 9, 20; **16**, 1-5; **2**, 14.
        1e. Oxygen. **4**, 23-33.
          1f. Oxidation. **2**, 78-82.
        2e. Hydrogen. **4**, 34.
        3e. Nitrogen. **4**, 50.
        4e. Carbon. **4**, 125.
        5e. Sulphur. **4**, 157.
        6e. Phosphorus. **4**, 193.
        7e. Chlorine. **4**, 92.
        8e. Sodium. **4**, 326.
        9e. Potassium. **4**, 321.
        10e. Calcium. **4**, 313.
        11e. Magnesium. **4**, 316.
        12e. Iron. **4**, 275.
        13e. Others which are rare.
          1f. Fluorine. **4**, 122.
          2f. Silicon. **4**, 184.
          3f. Lithium. **4**, 335.
          4f. Manganese. **4**, 295.
          5f. Iodine. **4**, 115.

2d. Some of the common inorganic compounds found in animal bodies.
1e. Air (air is a mixture, however, and not a compound).
1f. Composition. **4,** 82–84.
2e. Water.
1f. Composition. **4,** 40–43.
3e. Carbon dioxide. **4,** 138.
1f. Composition.
4e. Ammonia. **4,** 52.
1f. Composition.
2f. What is an alkali? **1.**
5e. Acids.
1f. What? **1,** 4, 75.
2f. Hydrochloric. **4,** 117.
1g. It is the only inorganic acid found free in the body.
6e. Salts. **1; 4,** 77.
1f. Common salt.
2f. Calcium carbonate.
3f. Sodium carbonate.
4f. Sodium phosphate.
2c. Physics.
1d. Physical terms used in speaking of animal physiology. **1.**
1e. Force.
2e. Resistance.
3e. Gravitation.
4e. Pressure.
5e. Tension.
6e. Friction.
7e. Weight.
8e. Work.

9e. Heat.
10e. Conduction.
11e. Radiation.
12e. Dissipation (referring to heat).
3c. Astronomy.
4c. Geology.
2a. Organic.
1b. Definition.
2b. Study of.
1c. Biology.
1d. Definition. **1.**
2d. Some common studies treating of.
1e. Botany.
2e. Zoology.
1f. Definition.
2f. Animals studied as to chemical composition.
1g. Organic chemistry.
1h. Albumens or proteids. **2,** 15–16.
1i. Serum albumen. **11,** V, 14.
2i. Fibrin. **11,** V, 32.
3i. Myosin. **11,** V, 30.
4i. Casein. **11,** V, 20.
2h. Hydrocarbons or fats. **2,** 16; **11,** V, 121-122.
1i. Palmatin.
2i. Stearin.
3i. Olein.
3h. Carbohydrates or starches and sugars. **2,** 16.
1i. Glycogen. **11,** V, 95.
2i. Glucose or grape sugar. **11,** V, 102.

3i. Lactose or milk sugar. **11,**V,113.
3f. Animals studied as to structure.
1g. Anatomy. **2,** 1–2; **5,** 5; **7,** 9; **6,** 4.
1h. Gross.
2h. Minute (histology). **2,** 2.
3h. Comparative.
4f. Animals studied as to function of organs.
1g. Physiology. **2,** 1; **5,** 5; **7,** 9; **6,** 4.
1h. Comparative.
5f. Animals studied as to healthy conditions surrounding them.
1g. Hygiene.
6f. Animals studied as to mental traits.
1g. Psychology. **1.**
7f. Animals studied as to development.
1g. Embryology. **1.**
8f. Animals studied as to classification.
1g. Main groups.
1h. Invertebrates. **1.**
1i. Definition.
2h. Vertebrates. **1.**
1i. Definition.
2i. Difference between vertebrates and invertebrates (zoologies).
3i. Main divisions of.
1j. Fishes.
2j. Batrachians or Amphibians.
3j. Reptiles.
4j. Birds.
5j. Mammals.
1k. Groups of. **22; 1; 20.**
1l. Monotremata (Duckmole).
2l. Marsupials.

31. Eutheria.
1m. Edentates (Armadillo).
2m. Sirenia (Sea cows).
3m. Ungulates.
4m. Cetaceans.
5m. Rodents.
6m. Carnivora.
7m. Insectivora.
8m. Chiroptera.
9m. Lemuroidea } Primates.
10m. Anthropoidea }
1n. Marmosets. }
2n. Cebidæ } New world monkeys.
3n. Cercopithecidæ (Baboons).
4n. Simiidæ (Anthropoid apes).
5n. Hominidæ or **men.**
4i. Reasons why man is classed as a vertebrate. **2,** 5; **3,** 2–5.
1j. Arrangement of body cavities and organs. **2,** 4, 5, 6, 7; **3,** 2-7.
2j. Spinal column.
5i. Why classed as an Anthropoid? **3,** 2.

THE CELL.

1a. Definition. **1.**
2a. History. **20**, under cell; **25,** 22.

3a. Structure, **11, I,** 3–9; **12,** 35–39; **15,** 5–8; **17,** 33–40; **6,** 9; **7,** 10–14; **25,** 22–28.
1b. The cell wall.
2b. The cell contents.
1c. The chief cell substance (protoplasm), **22,** 26.
2c. Nucleus.
4a. Size. **6,** 11.
5a. Shapes.
6a. Metabolism (assimilation). **6,** 13.
7a. Catabolism (dissimilation).
8a. Reproduction. **17,** 98.
1b. Direct division. **3,** 18.
2b. Indirect division. **3,** 19–22.
1c. Karyokinesis or mitosis. **17,** 100–104.
9a. Physiological properties. **3,** 22–28.
1b. Irritability.
2b. Conductivity.
3b. Contractility.
4b. Coordination.
5b. Spontaneity.
10a. Development of in the human body.
1b. Early stages of in the embryo.
2b. Differentiation of into tissues and organs, **17,** 40; **3,** 29.
1c. Definition of tissue.
2c. Definition of organ.
3c. Undifferentiated. **3,** 22.
4c. Physiological division of labor. **2,** 12; **3,** 30.
*)5c. Chief groups of tissues and organs.

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*) In some respects this grouping is an arbitrary one made for convenience only. All of the topics, except number 9d, will be considered later. Some teachers believe that the order in which the topics are discussed is of great importance, but since any one of the

1d. Supporting.
2d. Motor.
3d. Those concerned in nutrition (assimilative).
1e. Secretory (glands).
2e. Reception (alimentary canal).
4d. Circulatory (heart and blood vessels).
5d. Respiratory (lungs, air tubes and capillaries).
6d. Eliminative (kidneys, skin, etc.).
7d. Irritable and conductive (nervous system).
8d. Special sense (sight, hearing, smell, taste, touch and temperature).
9d. Reproductive.
10a. Bacteria. **17,** 105; **5,** 144; **27; 28; 31; 34; 37.**
1b. Beneficial.
2b. Disease producing.

LABORATORY EXERCISES.

CHEMISTRY.

MATERIALS. Small quantities of each: potassium chlorate; manganese dioxide; common salt; hydrochloric acid; sulphuric acid; magnesium ribbon; phosphorus; sulphur; metal sodium; metal potassium; pieces of zinc; yeast, sugar; commercial ammonia and common salt. An alcohol lamp or gas burner. A number of test tubes; two or three widemouthed bottles; some fine iron wire, a pan or dish for water; pieces of charcoal, coal, lignite and graphite; some lime

groups will depend more or less on the others there can be no great objection to following the usual order.

water; several corks; glass tubing; red and blue litmus paper.

---

1. EXPERIMENTS. Fill a test-tube one-fourth full with equal parts of potassium chlorate and manganese dioxide which have previously been mixed. Heat the tube gently over a flame and look for bubbles of gas, **oxygen,** which will be given off by the decomposition of the chemicals. Insert a splinter or match which has a spark on its end into the mouth of the tube. What is the effect? Has oxygen any color, taste or odor?

2. Make some more oxygen, or if the laboratory has an oxygen tank take it from that, and fill a bottle. Since oxygen is heavier than air the bottle may be filled by holding it mouth upwards and then allowing the oxygen to run in through a tube connected with the test-tube or gas holder. After the oxygen has been running into the bottle for a moment, remove the supply tube and prepare a fine iron wire by rolling up one end and dipping it into powdered sulphur. Ignite the sulphur. What is the color of the flame? Insert the wire with the burning sulphur into the bottle of oxygen. Vigorous combustion should follow and a part of the wire should be consumed. Would iron burn under ordinary circumstances in open air? The experiment just made illustrates rapid combustion. The same kind of combustion is illustrated by the burning of wood in the stove and oil in the lamp.

What happens to a piece of polished iron if put in a damp place? Iron rust is commonly formed by slow combustion.

What happens to damp straw when left in a pile? Is any heat given off?

Notice that two things always happen where oxidation goes on, viz., **new compounds** are formed and **heat** is given off. How do these facts help us to understand the human body?

3. Put a few pieces of common metallic zinc into a bottle or test-tube and pour on the same a small quantity of hydrochloric acid. Notice the bubbles of **hydrogen** that are generated. Hold a test-tube, inverted, over the mouth of the bottle until some of the hydrogen has been collected in the inverted tube. Still holding the tube inverted apply a lighted match to its mouth. What follows? Hydrogen explodes when mixed with air (oxygen.) It is rarely found free in nature and then only in very small quantities. Determine from the above experiment whether hydrogen is heavier or lighter than air.

4. Fill a pan or dish with water and float on this a slice of cork in which is fastened a piece of crayon. Hollow out the top of the crayon and in the hollow place a lump of phosphorus the size of a pea. Have ready a six ounce bottle with a mouth wide enough to easily pass over the floating cork. With a hot wire ignite the phosphorus and immediately invert the bottle over the same. What did the bottle contain before the experiment was performed? What

element is necessary before combustion can take place? What proportion of the air seems to be oxygen? Allow the bottle to remain in position after the experiment until the white fumes have been absorbed. The gas that now remains in the bottle above the water is **nitrogen,** a very inactive gas when free. Insert a lighted match into the bottle of nitrogen. Effect?

5. Examine pieces of hard and soft coal, charcoal, lignite, graphite (the lead in your pencil), burned bread, in fact any charred substance. These substances are **carbon.** Nearly all organic substances contain this element.

6. Examine some powdered and stick **sulphur.** Has it any odor? Burn a little sulphur and notice the odor.

7. Examine **phosphorus** as it is kept in a bottle. Why must it be kept under water? Never under any circumstance touch phosphorus with the hands. It will ignite at the temperature of the body and its burn is serious. With forceps put a small piece of phosphorus on a hard surface then rub it with a hard object. Why does it take fire? What is the chief source of commercial phosphorus? **4,** 193. Where do animals get their phosphorus?

8. Fill a test-tube one-sixth full of manganese dioxide then add a little hydrochloric acid. Warm the tube gently and look for the appearance of a yellowish green gas, **chlorine.** Notice the odor, but do not take too much of it into the nose.

9. Examine some metal **sodium** as it is kept under kerosene in the bottle, cut off a piece the size of a grain of wheat and drop it into a glass of water. What follows? Sodium combines readily with the oxygen of the water and oxidizes. Save the water in the glass for experiment 17.

10. Treat a small piece of metallic **potassium** in the same way that you did the sodium in experiment 9. Do they act exactly alike? Did either burn and explode and if so why? Save the water for experiment 17.

11. Examine lime stone, bone, clam or snail shells, marble and "Plaster of Paris." These all contain **calcium.** If the laboratory contains any metallic calcium it should be examined.

12. Hold a short piece of **magnesium** (ribbon) in a pair of forceps then ignite the magnesium by holding it in the flame. What is the color of the flame? What kind of a substance is left after oxidation has taken place? This experiment furnishes another illustration of rapid oxidation.

13. Heat a piece of charcoal red hot and then hold it in a bottle filled with air. After a few minutes, remove the charcoal and insert a lighted match. Why does it not burn? The bottle contains **carbon dioxide** gas. Pour a little lime water into the bottle containing the carbon dioxide. Shake. Result? This is a common test for carbon dioxide.

14. Put some lime water into a clean bottle and breathe into it through a glass tube. Effect?

What is present in your breath?

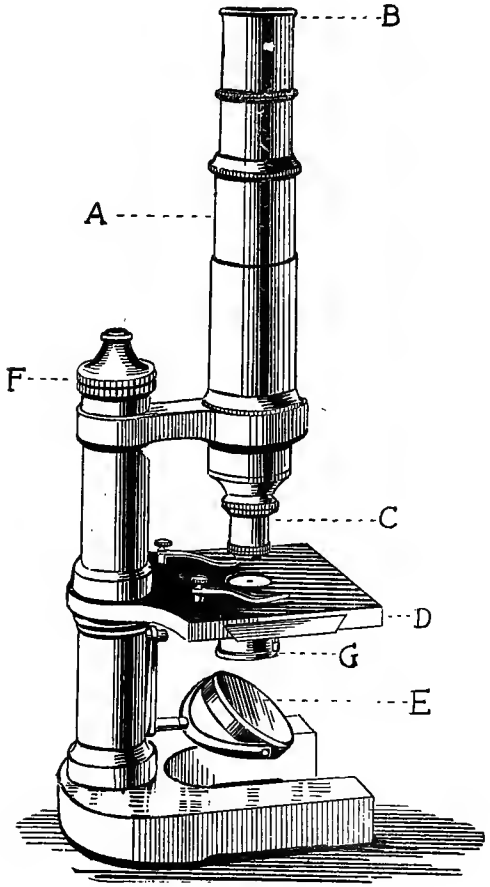
15. Put some small lumps of marble or limestone into a flask. Add some diluted hydrochloric acid, and close the flask with a cork fitted with a bent glass tube. When the action seems vigorous, let the gas escape into an empty bottle until you think it is full. Insert a lighted match into the bottle. Effect? Pour in a little lime water. Effect? What gas was given off from the limestone?

16. (This experiment may be made by one pupil for the class, or by the teacher). Into a bottle fitted with a cork and a delivery tube put a strong solution of sugar, and then add a little yeast. Let the delivery tube connect with a bottle filled with water inverted in a pan of water, then set the whole in a warm place. After a day or two examine the gas that has collected. Test with a lighted match, also with lime water. What gas was produced? The process that produced it is called fermentation.

17. Half fill a small test tube with commercial **ammonia** and heat gently. Observe the escaping gas, its color and odor. Moisten a strip of red litmus paper and hold it in the escaping gas. Effect? This is the test for alkalis, and is called an alkaline reaction. The gas that was produced was **ammonia,** which is an alkali. Test with red litmus paper the water left from experiments 9 and 10. Result?

18. Put a small amount of common salt into a test tube and add some sulphuric acid. Observe the color and odor of the escaping gas, **hydro-**

chloric acid. Hold some moistened blue litmus paper in the gas. Effect? This is an acid reaction.



A COMPOUND MICROSCOPE.

THE MICROSCOPE.

A good compound microscope is indispensable for thorough work in practical physiology. The student should have access to one equally as good as that shown in the cut. It should be fitted with two objectives, a one inch and a one-fourth or one-sixth inch, and one or two eye pieces. A simple instrument is to be preferred for beginners and the extra high powers are not desirable, although it is well to have one instrument fitted with high power objectives for the use of the teacher in demonstrations.

The chief parts of the microscope are the **draw tube,** *A*, the **eye piece,** *B*, the **objective,** *C*, the **stage,** *D*, the **mirror,** *E*, the **fine adjustment screw**, *F* and the **diaphragm,** *G*.

The **mirror** is used to catch the light from some window and to throw it through the object, the objective and eye piece to the eye. Before trying to focus the instrument the first thing to do, always, is to adjust the mirror.

Objects to be examined with the compound microscope by the ordinary methods must be very thin so that light can be transmitted through them. They are generally placed on a clear **glass slip,** 1x3 inches in size, and then covered by a very thin piece of glass known as the **cover glass.** Nearly all objects need to be mounted in water or some other transparent medium to be seen to the best advantage.

The **high** and **low power objectives** can easily be distinguished from the fact that the former has a very much smaller lens than the latter. The high power objective focuses much nearer the object

than the low, is much more difficult to focus, it requires more light and the object does not appear so distinct as when under the low power.

The **diaphragm,** as usually arranged, is a circular brass plate containing holes of various sizes, which may be revolved under the circular hole in the stage and thus regulate the amount of light that is reflected through the object. The more opaque the object, generally, the greater the amount of light required. The high power objective will require more light than the low and on dark and bright days the light must be regulated to suit the object.

In the instrument shown in the figure the **draw tube** is made to slide with the hand. To focus upon an object the tube should be pushed down until the lower end of the objective nearly touches the glass, then, with the eye looking into the eye piece, the tube should be withdrawn, slowly, until the object appears in view. Now with the fine adjustment screw move the tube until the object is clearly in focus.

THE USE OF THE MICROSCOPE.

MATERIALS. A slide with the letter *F* or some other letter mounted on it, or if this is not at hand, cut from a paper some letters that can easily be distinguished when inverted; a slide with some wool fibers mounted; a slide with cotton fibers; a slide with two colors of silk mounted so that they cross each other; a slide with mounted cats hairs; and a box with plain glass slips and cover glasses. (See page 14.)

1. Examine the microscope and review its parts. Make a rough sketch of it and name the parts. Keep full notes and make clear and accurate drawings of everything observed.

2. Place the slide of the letter *F* on the stage of the microscope and fasten it with the clips. Adjust the mirror with the low power objective in position, slide the draw tube down until the lower end of the objective is about one-fourth of an inch from the object. Place the eye in position and slide the draw tube up **slowly** until the object is seen. Now with the fine adjustment screw focus until the letter appears distinct. What is wrong with the letter? Have you placed it in the microscope wrong? Move it a little while looking into the tube. What happens? How is the letter inverted? (In how many ways?) What does the microscope seem to do to objects that are placed under it?

3. Place a slide of wool fibers under the microscope and focus carefully on it with the low power. Try with a smaller diaphram. Are the fibers cylindrical? Are they smooth?

4. Place the high power objective in the microscope and push it down very near the object but do not touch the cover glass. While looking into the tube of the instrument run it up with the fine adjustment screw. Work carefully. You will need more light for the high power. Why? After the fibers are in focus note the following: Are they rough? Can you now account for the sensation you receive when you touch wool?

How? Can you distinguish cells in the fibers? Draw two or three fibers.

5. Examine a slide of cotton fibers, first with the low then the high power. Shape of the fibers? How alike and how different from those of wool? Draw.

6. Examine the colored silk fibers, first with the low then the high power. How alike and different from wool and cotton? Examine very carefully and determine the order in which the various colors are placed, (which is above and which below? Do this by focussing, carefully, first on one and then the other). Make a drawing and indicate the colors and order.

7. Examine the hairs of the cat or rabbit. Compare with the wool and the fibers of silk and cotton. What is the shape of the cat's hair? If there are two colors in the hair, how do they differ?

8. Take a plain glass slip and place on it a few fine fibers from your handkerchief, dress or coat, add a drop of water and then apply, carefully, a cover glass and examine. Try to get both wool and cotton. Compare with what you have seen before.

9. Mount a piece of hair from your head in the same manner as the fibers described above. With the high power, look for the three parts:
   a. An outer roughish portion, the **cuticle.**
   b. The dark **fibrous material.**
   c. In the center, the tube-like part, **medulla.** If air bubbles are pres-

ent in this part of the hair, it appears white.

Make drawings of the human hair.

10. Examine hairs from various animals and make notes and drawings.

11. Prepare permanent slides of some of the fibers and hairs by the following method: Place the perfectly dry fibers or hairs in turpentine or clove oil for a few minutes and then put one or two on a glass slip, add a drop of Canada balsam, apply a cover glass, then set aside in a horizontal position for the balsam to harden. In applying a cover glass, first touch one edge then let the other down slowly.

NOTE. The preceding exercises are intended mainly for the drill they give in the use of the microscope and not especially for the information gained, although they may aid the student in distinguishing some of the more common foreign objects which are likely to appear under the microscope, along with other preparations, in all work with the instrument. The glass slips and cover glasses must be perfectly clean before they are used. The same is true of all parts of the microscope. Remember never to touch the lenses with the fingers and if any dirt accumulates on them, remove it with a soft handkerchief. If the object you are examining does not appear clearly defined, look for dirt or water on the objective or eyepiece of your microscope. No satisfactory work can be done until the student can accurately and easily focus the microscope, so the foregoing exercises should be repeated, if necessary, until the manipulation becomes easy.

THE CELL.

MATERIALS. Cork; a razor; a bottle of iodine for staining (see appendix); leaves of the geranium and some logwood stain, such as hæmatoxylin or hæmalum. In general it will be found more satisfactory to purchase this stain, as well as others mentioned hereafter, from some reliable dealer. The quantity of the stains

used, is usually too small to justify the teacher in trying to make them up. Should the teacher, however, desire to make them, formulæ will be found in the appendix. Collect several bottles of pond water, with some of the ooze from the bottom and pieces of aquatic plants. About two days before this work is to be taken up in the laboratory, prepare three bottles as follows: Partially fill two of the bottles with water and in one drop a piece of meat. In the other, place some hay. Both bottles should be kept in a warm place. In the third bottle, put some water, a little flour, one-fourth of a teaspoonful of sugar, and then add one-half of a yeast cake. This third bottle may be prepared the night before it is to be used, but it should be kept warm during the night.

1. With a sharp knife or razor, shave off a very thin piece of cork, place it on a glass slip with a drop of water and apply a cover glass. Examine, first with the low, then the high power and notice:
   a. The rectangular spaces, **cells,** which compose it.
   b. That the spaces are empty, or that only the cell wall portion is present.
2. Tear a geranium leaf crosswise so that a little of the epidermis from the under-side will be removed. Mount this in water with the outside up, then examine with the low power and notice:
   a. The numerous cells with irregular walls.

b. Other smaller cells, somewhat half-moon shaped, which are arranged in pairs to form the breathing-pores of the plant.

3. Remove the cover glass from the specimen just examined and apply a drop of hæmatoxylin. Allow the stain to remain for five or ten minutes then drain off, apply water and again the cover glass. Examine now with the high power and notice:
   a. The cell walls, irregular in shape.
   b. The shape of the cells which form the breathing-pores.
   c. A purplish dot, the **nucleus,** may be found in some of the cells. The nuclei are shown exceptionally well in the epidermis of the Wake-robin leaf.
4. With a dull knife or other clean object, scrape a few cells from the cheek on the inside of the mouth. Mount without staining and observe:
   a. The large flat cells.
   b. The rather clear nucleus.

   Remove the cover glass and allow the material to dry on the slide. The process may be hurried by gently warming over a flame. When dry, apply a few drops of hæmatoxylin stain, and when it has remained for five minutes, wash in water, apply a cover glass and examine. The nucleus should appear distinctly stained.
5. If specimens can be obtained, the **amœba** should be examined here. This one-celled animal can usually be found in the summer time

on the stems of aquatic plants, in the ooze at the bottom of ponds, lakes and rivers, and is frequently found on clam shells, and on the walls and other objects of the aquarium where clams are kept. Under the microscope, the amœba may be distinguished by the following characters:

a. It is almost transparent.
b. It puts out **pseudopodia,** or false feet.
c. Its movements are very slow.
d. The granular central portion.
e. A more or less clear outer portion.
f. A **nucleus.**
g. A **contractile vesicle.** Notice that the vesicle gradually enlarges and then suddenly collapses.
h. The many small particles in the granular portion, **food particles.**

Tap on the cover glass to see if the amœba is sensitive. Make drawings of the amœba showing all of its parts. See outline of the cell for references on the amœba.

6. Examine drops of water from the first two bottles referred to under **materials,** using the high power, and look for **very small** bodies that are rapidly moving about, **bacteria.** Some of these may be spherical in shape, others look like straight rods and still others like curved rods. Some larger forms, **infusorians,** may be found.

Study preparations from both bottles carefully and make drawings of what you observe.

The bacteria are plants, and the infusorians animals.

7. Examine a drop of yeast from the third bottle prepared. Notice:

a. The numerous roundish bodies, **starch grains.**

b. Between the starch grains, numerous small bodies, often oblong in shape, **yeast plants.** Sometimes these yeast plants are budding.

c. Apply a drop of iodine, which will stain the starch grains purple, if weak, and black if strong, and the yeast cells yellowish. The yeast cells can now be readily distinguished.

Make drawings of the yeast.

The action of yeast on starch and sugar is to produce **alcohol** and carbon dioxide, hence yeast is necessary in brewing for the alcohol it produces, and in the bakery for the carbon dioxide, which causes the dough to expand and become light.

SUPPORTING TISSUES.

THE SUPPORTING TISSUES.

1a. The skeleton. **2; 3; 6; 7; 8; 18; 19; 25.**
1b. Of what consist?
1c. Exo-skeleton. **3,** 63.
1d. What it is? Illustrations.
2c. Endo-skeleton. **3,** 63.
1d. Consists of what?
1e. Connective tissues. **2,** 18; **3**, 100; **14**, 14; **17**, 53; **25**, 104; **6**, 15; **18**, 45.
1f. Nature of.
2f. Kinds.
1g. Areolar. **3**, 100; **14**, 15.
1h. Where found?
2h. Structure.
3h. Properties.
4h. Physiology.
5h. Adipose. **18**, 49; **3**, 107; **14**, 15.
2g. White fibrous. (See references under 1e.).
1h. Where found?
2h. Structure.
3h. Properties.
4h. Physiology.
3g. Yellow fibrous or elastic. (See references under 1e.).
1h. Where found?
2h. Structure.

3h. Properties.
4h. Physiology.
4g. Irregular forms. **3**, 103.
1h. Where found and properties?
3f. Chemical composition of connective tissues. **3**, 102.
4f. Development of connective tissues. **18**, 48.
2e. Cartilage. **3**, 98; **2**, 17; **7**; **25**; **6**; 5; **14**; **18**, 51.
1f. Nature of.
2f. Structure.
1g. Cells.
2g. Intercellular substance.
3f. Kinds of.
1g. Temporary.
2g. Hyaline.
3g. Cellular.
4g. Fibro-cartilage. **3**, 104.
3e. Bony skeleton. See under index of Nos. **2**, **3**, **6**, **7**, **8**, **15**, **18**, **19** and **25**.
1f. Axial skeleton. **2**, 20.
1g. Parts of.
1h. Vertebral column.
1i. Number of bones.
2i. Anatomy of a typical vertebra. **2**, 23; **3**, 66; **25**, 17.
3i. Divisions of.
1j. Cervical. **3**, 68; **18**, 147.
1k. Number of bones.
2k. How distinguished from other vertebræ.
3k. Atlas and axis. **2**, 25; **18**, 148.

11. Structure and physiology.

2j. Dorsal.

1k. Number.

2k. Location and how distinguished.

3j. Lumbar.

1k. Number.

2k. Location and how distinguished.

4j. Sacrum.

1k. Divisions of.

2k. Why are the vertebræ here united.

5j. Coccyx.

1k. How explained?

2i. Physiology of the spinal column.

2, 34; **3,** 71.

1j. Curves in.

1k. Advantages.

2j. Flexibility. Cause.

2h. Ribs.

1i. Shape.

2i. Total number.

3i. The usual division into groups.

3, 72; **6,** 31.

1j. Reasons for each division.

4i. Costal cartilages.

3h. Sternum.

1i. Structure.

2i. Function.

4h. The skull.

1i. The cranium.

1j. Number and location of each bone.
2j. Fontanelles. **1.**
3j. Sutures. **1.**
2i. Face.
1j. Number and location of each bone.
3i. Hyoid bone.
1j. Its use.
2f. Appendicular skeleton. **3,** 77.
1g. Pectoral arch.
1h. Scapula.
1i. Location, shape, articulations.
2h. Clavicle.
1i. Location, shape, articulations.
2i. Comparative anatomy of. **26,** 71–73; **29,** 107–109.
3h. Humerus.
1i. Location, shape, articulations.
4h. Ulna and radius.
1i. Location, shapes, articulations.
2i. Physiology of.
5h. Carpal bones.
1i. Location, number, names. **18,** 273.
2i. Physiology.
6h. Metacarpal bones.
1i. Location, number.
7h. Phalanges.
1i. Location number.
2g. Pelvic arch or girdle.
1h. Innominate bones.
1i. Number, shape, articulations.

2i. Acetabulum.
3i. Thyroid foramen. **3,** 79.
4i. Development of. **18,** 280.
5i. Physiology.
2h. Femur.
1i. Description; articulations.
3h. Tibia and fibula.
1i. Shapes, articulations.
4h. Patella.
1i. Location, description.
2i. Development of. **18,** 294.
3i. Physiology.
5h. Tarsal bones.
1i. Number, names. **18,** 301.
2i. Development of the astragalus. **3,** 81.
3i. Physiology of.
6h. Metatarsal.
1i. Number, location.
7h. Phalanges.
1i. Number.
2i. Physiology.
3i. How illustrate specialization? **26,** 84.
8h. Comparative anatomy of bones of the lower limbs. **15.**
3g. Comparison of bones of upper and lower limbs. **2,** 29; **3,** 80.
1h. Likenesses.
1i. Compare each set of bones and state likenesses.
2h. Differences.
1i. The patella.

2i. Movements of the ulna and the radius compared with that of the tibia and fibula.
3i. The hand and foot.
4g. Some peculiarities of the human skeleton.
1h. The balancing of the skull.
2h. The spinal column.
3h. The pelvis.
4h. Length of the lower limbs. Effect?
5h. Arched instep. Value?
3f. Structure of bone.
1g. Gross structure. **2,** 36; **3,** 85; **25,** 88; **14,** 24; **18,** 54.
1h. Arrangements of bones in groups on basis of shape.
2h. Covering of bones.
1i. At the ends in long bones.
2i. Other portions of the bone.
3i. Nature and use of this covering.
3h. Enlargements at the ends in long bones. Use?
4h. Name of the middle portion of a long bone.
5h. Internal structure of a long bone.
1i. Name of the cavity.
1j. With what filled?
1k. Use of the marrow.
2i. Inside structure of the enlarged ends.
1j. With what filled?
3i. What reason for bones being hollow?

2g. Minute structure of bone. **2,**40; **3,**87; **25,** 88; **14,** 27; **18,** 56; **30,** 174.
1h. Haversian canals.
1i. Location, size, use.
2h. Lamellæ.
1i. Location and arrangement.
3h. Lacunæ.
1i. Location, use.
2i. Bone corpuscles.
4h. Canaliculi.
1i. Location, use.
4f. Chemical composition of bone. **2,** 42; **14,** 24; **18,** 58.
1g. Organic matter.
1h. Nature of.
2g. Inorganic matter.
1h. Nature of.
3g. Chemical composition as illustrated, in general, by the manufacture of gelatine, bone black, bone ash phosphorus and fertilizers. **20.**
5f. Development of bone. **25,** 93; **18,** 59.
6f. Hygiene of bones. **6,** 47-52; **2,** 43.
1g. In reference to clothing.
2g. In reference to the habits of the person.
3g. Fractures.
7f. Articulations. **2,** 46; **3,** 91; **18,** 315.
1g. Definition.
2g. Classes as to movement.
1h. No movement (sutures).
2h. Little movement (spinal column).
3h. Free movement.

1i. Joints.
1j. Need of.
2j. Study of the hip joint. **2**, 47; **3**, 92.
1k. Parts.
1l. Ligaments (two kinds).
2l. The ball.
3l. The socket (acetabulum).
4l. Articular cartilages.
5l. Synovial membrane.
6l. Synovial fluid.
1m. Physiology of.
2k. Physiology of.
1l. Effect of air pressure on the joint. **3**, 92.
2l. Movements.
1m. Flexed, extended, abducted, adducted, circumducted, rotated.
3j. Locate the other ball and socket joints of the body.
4j. Hinge joints.
1k. Describe and compare with ball and socket joints.
2k. Locate several of these.
5j. Pivot joints.
1k. Describe and locate.
6j. Gliding joints.
1k. Describe and locate.
7j. Hygiene of joints.
1k. Dislocation.
2k. Sprain.

LABORATORY EXERCISES.

CONNECTIVE TISSUES.

MATERIALS. Get from the butcher several inelastic tendons, which are usually found near joints; and a yellow elastic ligament, which is found in the back of the neck of the cow or sheep. Have ready also a sharp razor; Farrant's solution; picro-carmine; a one per cent. solution of glacial acetic acid; alcohol and hæmatoxylin. Place pieces of both kinds of connective tissue in 50 per cent. alcohol for 24 hours then 70 per cent. alcohol and let them remain in the latter until ready for use. The tissues will be hardened by the alcohol so that they can be cut into sections with the razor.

1. WHITE FIBROUS OR INELASTIC TISSUE. Pull a tendon to see whether or not it will stretch.
2. Tear a fine strip from a tendon and cut off a short piece, place it on a glass slip with a drop of water, then with two needles or pins tease the fibers apart as much as possible. Apply a cover glass and examine with low and high powers. Notice the fine fibers that make up the tissue. Draw.
3. With a sharp razor cut thin cross sections of a hardened tendon (see appendix for methods of cutting), place these in picro-carmine until well stained, then mount them directly in Farrant's solution, **without washing.** Notice:

a. The outer covering or **sheath,** which sends branches in between the bundles of fibers.

b. The **spaces** between the bundles, somewhat star-shaped and dark in appearance if they contain air.

c. The cut ends of the fibers.

4. Cut longitudinal sections of the hardened tendon and stain them in hæmatoxylin, mount in water and observe:

a. The longitudinally arranged fibers.

b. Between the fibers, rows of elongated **tendon cells**, or rather the nuclei of tendon cells.

5. In connective tissue, cartilage and bone, the chief function of the cells is to build up a secondary substance called, in the cartilage, the **matrix** or **intercellular substance.** After this is done the cell becomes rather insignificant. This fact explains why the cell structure is not more definite in connective tissue.

6. Boil for some time a few bundles of white fibrous connective tissue. What effect? Can you draw any conclusion from this experiment as to why we cook meat?

1. THE YELLOW FIBROUS OR ELASTIC TISSUE. Take a piece of the ligament found in the neck of the cow and pull it with the fingers. Describe its action. Compare with the white fibrous tissue.

2. Tear as small a strip as possible of the tissue then tease it on a glass slip and mount in water. Notice:

a. The shape and size of the fibers as compared with white fibrous tissue.

b. Look carefully to see if any of the fibers branch.

c. Observe the curled ends of some of the fibers.

d. Put a drop of acetic acid on the slide and allow it to run under the cover. Notice that the fibers are not affected and no nuclei are made visible as in the white fibrous tissue.

3. Cut cross sections, stain them in picro-carmine, mount in Farrant's solution and notice:

a. The **elastic fibers,** stained yellow.

b. The **connective tissue** which binds the yellow fibers together, stained red.

c. The **ends** of the fibers. Shape?

4. Make a longitudinal section, stain with picro-carmine and notice the fibers and connective tissue. Draw.

5. Boil some of the yellow elastic tissue the same length of time you did the white fibrous. Effect?

CARTILAGE.

MATERIALS. Get a joint from the leg of a calf and have ready some hæmatoxylin, and a one per cent. solution of silver nitrate.

1. HYALINE CARTILAGE. With a sharp razor make some thin sections of the cartilage found on the end of the fresh joint. Make the sections in different directions. Mount a section in normal salt solution and observe:

a. The **cartilage cells,** often in pairs.

b. The substance between the cells, the **matrix** or **intercellular substance.**

c. Are the cells evenly distributed throughout the entire section? If not where are they most numerous?

2. Remove the cover glass from the section just examined and apply a drop of hæmatoxylin. Allow the stain to remain for five minutes then wash the section in water and replace the cover glass. Notice the stained cells.

3. Take a fresh section and put it in silver nitrate solution for five minutes, wash in water, then let it stand in water in the sunlight or bright day light until it turns brown. Mount and examine. Notice that the matrix has been stained brown by the silver.

4. Sections described under paragraphs 2 and 3 may be preserved permanently if mounted in glycerine or glycerine jelly. See appendix for methods.

BONES.

MATERIALS. A dry bone; a fresh long bone; a file; a fine whetstone, or better two such stones; a saw; some hydrochloric acid and some dry Canada balsam.

1. GROSS STRUCTURE. Examine any long dry bone, such as the human femur or humerus or a similar bone from some domestic animal, for the following points:

a. The enlarged ends, the **articular extremities.**

b. The smaller central portion, the **shaft.**

c. Notice the **smooth surfaces** on the enlarged ends. What use?

d. Notice the **rough places** on the shaft and enlarged ends. What use are they?

e. Look for small **circular holes** entering the bone. What are they?

2. If a prepared specimen is not at hand, saw a long dry bone in two lengthwise and notice:

a. The **thickness** of the walls of the shaft. Compare with the walls of the articular extremities.

b. Notice the cavity in the shaft, **medullary cavity.** How far does it extend into the ends?

c. What takes the place of the cavity in the ends of the bones?

3. Make a drawing showing the internal structure of the sawed bone.

4. Examine the outside of a fresh bone. How do the articular surfaces differ from those of the dried bone? Look for the rough places mentioned under the gross structure of the dried bone. Saw open the fresh bone in the same manner that you did the dried one.

a. Look for the medullary cavity. What does it contain? Of what is the substance composed? What color is it?

b. What do you find in the ends? What color? How does it differ from the contents of the shaft?

c. Compare the inside of a fresh bone with that of the dried one.

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1. MINUTE STRUCTURE. In order to examine the minute structure of a bone it is necessary to have a prepared thin section. It is better to have two, one made lengthwise of the bone and one crosswise. Such sections may be prepared in the following manner: Saw as thin a slice as possible, then rub it on a file until it is quite thin, much thinner than you will at first think it should be, then rub it on a very fine whetstone with water, or better between two such stones, until it is so thin that light will pass through it.

Try frequently under the microscope and continue grinding until all the parts can be made out. After the grinding has gone far enough, allow the section to dry, then place it on a glass slip and cover with a cover glass. Run cement around the cover glass and the section is finished. The section may, however, be mounted in water and studied. A better way to mount it permanently is to allow it to dry thoroughly then place on a glass slip a small lump of dry Canada balsam and warm it gently until it melts. While warm place the bone section in the balsam, apply the cover glass, then cool the slide as quickly as possible. The cooling must be rapid in order to prevent the balsam from penetrating the section, for in so doing the air is driven out and the section becomes too transparant to show the structure.

Since the preparation of bone sections is a long, tedious process, not everyone will care to do it but most schools possessing a compound microscope will have prepared sections at hand.

2. Under the low power notice:
   - *a.* If a longitudinal section, some openings running lengthwise, the **Haversian canals.** If a cross section is examined the **ends** of these canals will be seen.
   - *b.* All through the bone and in concentric circles around the cross sectioned Haversian canals, notice the black spots, the **lacunæ.**

2. Under the high power (500 diameters) notice:
   - *a.* In a cross section the concentric layers of long plates surrounding an Haversian canal, the **lamellæ.**
   - *b.* Where, with reference to the lamellæ, are the lacunæ located?
   - *c.* A number of fine lines, tubes, running out from one lacuna to another, the **canaliculi.**
   - *d.* Look for canaliculi running into the Haversian canals. What is the use of the canaliculi? What is the use of the lacunæ?

3. Make a careful drawing of some part of the section showing all the minute structure of bone.

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1. CHEMICAL COMPOSITION. Take a small bone such as the tibia of a chicken (drum stick) or the rib of a sheep, and find a tall wide necked

bottle into which the bone can be placed. Fill the bottle with a solution composed of one part hydrochloric acid and five parts water. After cleaning the bone of all fat or flesh, place it in the solution and allow it to remain over night. If on examination the next morning the bone is not entirely soft, allow it to remain longer. How do you explain the change?

2. Place a piece of limestone or marble half the size of a grain of corn in the solution and notice what takes place. Compare with the action on the bone.

3. Place a bone in the fire and allow it to remain until completely burned. What is left? Try a piece of the ash in the acid solution. What conclusion do you reach concerning the chemical composition of bone?

JOINTS.

MATERIALS. Get from the butcher a few joints of different kinds from any small animal so that they will be convenient to handle.

1. Take up one of the joints and move its parts.
   a. In how many directions can it be moved?
   b. Do any of the joints move like a hinge?

2. Examine carefully the tissues surrounding one of the joints.
   a. In what directions do these tissues run? Make a drawing showing the arrangement of the **ligaments,** after the fat has been removed.

3. With a sharp knife carefully trim away this outer covering, **capsular ligaments,** of the joint.

a. Look for any fluid, the **synovial fluid,** that may escape. How does this fluid feel when rubbed between the fingers? Its use?

b. Pull the joint apart and notice the **articular cartilages.** Did the joint contain a round ligament? Such ligaments are found in some joints, as the hip joint in the human body.

MOTOR TISSUES.

MOTOR TISSUES.

1a. Motion in plants and animals. **3,** 119.

2a. General characteristics of motor tissue. **3,** 119; **17,** 469; **6,** 57; **5,** 9; **25,** 112.

3a. Kinds of motor tissues.

1b. Amœboid cells. **2,** 151; **3,** 110; **9,** 170; **25,** 62; **12,** 157; **11,** I, 168.

1c. Undifferentiated nature of.

2b. Ciliated cells. **3,** 110; **9,** 170; **17,** 46; **12,** 154; **11,** I, 164. **13,** II, 559.

1c. Structure. **30,** 135-140.

2c. Location.

3c. Physiology of.

3b. Muscles. **2,** 52; **3,** 112; **6,** 57-78; **5,** 9-28; **5,** 371-381; **8,** 33-53; **23,** 355-461.

1c. Number in the body. **2,** 52.

2c. Variation in size and length.

3c. Uses of muscles.

1d. Primary. **2,** 52.

2d. Secondary.

4c. Classes as to structure and location.

1d. Skeletal muscles (striped). **3,** 113.

1e. Parts of a typical one. **2,** 52; **3,** 112.

1f. Tendons.

2f. Body or belly.

2e. Origin and insertion. **2,** 55; **3,** 115.

3e. Forms as to shape. **2,** 55; **3,** 116.

1f. Biceps.

2f. Triceps.

3f. Penniform.
4f. Bipenniform.
5f. Digastric.
6f. Polygastric.
4e. Arrangement of muscles in pairs. **2,** 56.
5e. Gross structure of striped muscles. **2,** 57; **3,** 117. **11,** I, 86. **13,** II, 562.
1f. Covering.
2f. Division of into fasciculi.
3f. Further division of the fasciculi. **3,** 117.
6e. Histology of striped muscles. **2,** 58; **3,** 117; **25,** 114; **11,** I, 90; **13,** II, 562.
1f. The muscle fiber. **3,** 117-122; **25,** 119; **30,** 193.
2d. Plain muscular tissue. **2,** 59; **25,** 121; **12,** 149. **11,** I, 158; **13,** II, 571.
1e. Where found?
2e. Structure.
1f. Compare with striped muscle.
3d. Cardiac or heart muscle. **2,** 61; **3,** 123; **25,** 123. **13,** II, 571.
5c. Chemical composition. **2,** 61; **3,** 123; **25,** 123; **17,** 474; **12,** 104; **11,** I, 97; **13,** II, 575.
1d. Difficulties in determining.
2d. Chief constituents.
3d. Beef teas and extracts. **3,** 125.
6c. Physiology of muscles.
1d. Properties of muscular tissue. **17,** 473.
1e. Contractility. **3,** 127; **13,** II, 575.
1f. Effect of differentiation.
2f. Change of form but not quantity.

2e. Irritability. **3,** 128; **10,** 38; **13,** II, 585.
1f. Stimuli. **3,** 128; **25,** 125; **17,** 481; **12,** 111.
1g. Nervous impulse.
2g. Electric. **10,** 68.
3g. Heat. **10,** 66.
4g. Chemical.
5g. Mechanical.
6g. How show that these do not simply act on the nerves? **3,** 130.
2f. Theory of "vital spirits" of the older physiologists. **3,** 130.
2d. A simple muscular contraction. **3,** 130; **25,** 126; **14,** 41; **17,** 490; **12,** 82; **11,** I, 69.
3d. Physiological tetanus. **3,** 133; **25,** 131.
1e. Effect of continuous shock? **3,** 134.
4d. What is rigor mortis? **3,** 123-457; **25,** 134; **17,** 502.
5d. Source of muscular energy. **3,** 140; **25,**135.
6d. General physiology of muscles. **2,**64; **3,**144.
7d. Special physiology of muscles.
8d. Levers. **2,** 64; **3,** 145; **25,** 138; **17,** 505.
1e. First class or order.
1f. Explain and give illustration from the body.
2e. Second class, with illustration.
3e. Third class, with illustration.
4e. Advantages and disadvantages under which muscles work.
1f. Muscular work, in general. **3,** 148.
9d. Pulleys. **2,** 67.
10d. Posture of the body and how kept. **2,** 67;

17, 506.

11d. Locomotion.

1e. Walking. **2**, 69; **17**, 510.

2e. Running. **2**, 71; **17**, 510.

3e. Leaping. **3**, 153.

*) 12d. General physiology of muscle and nerve. **10**, 32-152; **14**, 40; **12**, 73; **11**, I, 57.

7c. Blood vessels of muscles. **14**, 39; **25**, 131; **13**, II, 567.

8c. Hygiene of muscles. **2**, 72; **25**, 141; **6**, 78-96.

1d. Necessity of.

2d. Varieties of exercise.

3d. The gymnasium.

LABORATORY EXERCISES.

AMOEBOID CELLS.

1. Draw a drop of blood from the little finger near the root of the nail by inserting the point of a needle under the skin. Place the drop on a glass slip which has been warmed to about the temperature of the body, dilute with a little normal salt solution (six parts of salt to one thousand of water), apply a cover glass and look for movement in the **white corpuscles.**
2. Sketch two or three of the corpuscles in different positions.
3. What physiological properties do the white

*) A full discussion of this topic can be undertaken only with advanced classes. It may be desirable to omit it until after the study of the nervous system.

corpuscles seem to possess that they may move thus?

NOTE. The success of these exercises on amœboid cells depends upon the temperature at which the preparation is kept, and upon the power of the microscope. The blood should be kept at about the temperature of the body, and the microscope should magnify at least 500 diameters. The temperature of the preparation may be easily regulated by having at hand a strip of sheet copper about one inch wide and a foot long. One end of the strip should be placed on the glass slip near the cover glass, after the slide has been fixed in the microscope, and the other end should be supported by some object so that it will be level. Place a spirit lamp or other heat under the strip and move it about until you find that the blood is being nicely warmed. Any desired temperature may thus be obtained.

CILIATED CELLS.

MATERIALS. A frog; a piece of wire; normal salt solution; some sweet oil; a clam and some one-tenth per cent. osmic acid.

1. Kill the frog by severing the spinal cord just back of the head, then probe the brain to destroy it. Remove the frog's lower jaw with a pair of scissors, cutting well back so as to expose the pharynx and œsophagus. Pin the frog on a board so that the cut surface will face upwards, wash the mucus from the roof of the mouth with water then drop some pieces of powdered cork on the hard palate between the two eyes. Notice that the pieces of cork travel slowly towards the stomach.
2. Scrape a little of the mucous coat from one side of the roof of the mouth of the frog, tease this in normal salt solution on a glass slip, apply a cover glass and look for **ciliated cells.**

a. Can you see the cilia?

b. What effect have they on the blood corpuscles and other loose cells?

c. What peculiar movement of the cilia causes the floating matter to move in one direction only?

d. Put some oil around the edge of the cover glass to prevent evaporation, and set the slide aside for a time. Examine occasionally to see how long the cilia will live. A better idea can be had concerning them after they begin to move slower.

2. Open the clam and find the broad membranous portion, the **gills.** (If you are not sure of these, place the opened clam in water and the gills will be seen to float up). Cut out a small portion of a gill and mount it in water and look for cilia.

a. How do they compare with those of the frog?

b. Study again the manner of movement.

3. Take the frog used in the above experiment and on the portion of the roof of the mouth not scraped let fall two or three drops of osmic acid. Place the frog on its back under a tumbler or glass jar, where it should remain for half an hour or longer, then let water run gently over the blackened portion to remove the acid. Scrape the blackened portion gently and mount some of the cells in dilute glycerine. Be sure that the cells are well separated before applying the cover glass. This can easily be done

by using two needles.

a. What is the shape of the cells?

b. Look for the cilia. Are they in a row around the edge of the cell or are they spread over its entire surface?

c. Compare the length of the cilia with the length of the cell.

d. Draw cells in various positions.

e. Preserve the section permanently by running cement around the edge of the cover glass.

STRIATED MUSCLE.

MATERIALS. Get from the butcher a complete long muscle with the tendons attached; the frog used in the study of ciliated cells, if the muscle study is taken up in a short time after the ciliated cell study, otherwise a fresh frog should be killed. Muscle changes in a short time after death. Have ready some glycerine; borax carmine; a grashopper or beetle, needles and, if possible, a microtome and paraffin imbedding outfit.

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1. GROSS STRUCTURE. In the long muscle with attached tendons notice:

a. Is there any distinct point where muscle leaves off and tendon begins?

b. Try to prove for yourself that the tendons really extend **through** the muscle, forming many little cylindrical tubes in which the real muscular tissue lies.

c. Look for a covering over the muscle,

perimysium. With forceps strip some of it off.

2. Cut the muscle in two crosswise.
   a. Look for white connective tissue extending through the muscle.
   b. Notice that the muscle is divided into rather large bundles each surrounded by connective tissue.
   c. Find a division of the large bundles into smaller bundles, **fasciculi.** Have you seen these fasciculi in cooked meats?
   d. Notice the fat between the bundles.
3. Make a longitudinal cut through the muscle and notice the points indicated under the cross section.
4. Make drawings of cross and longitudinal sections and indicate by colors or shading the different parts.
5. Examine boiled and roast beef the first time it appears on the dinner table.

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1. Minute Structure. Remove the skin from one of the legs of the frog used above, and with forceps strip off the white connective tissue, **perimysium.** Take hold of a small portion of the muscle and strip it down in a similar manner and at once place it on a glass slip with a little normal salt solution. With needles seperate the fibers as much as possible, then apply the cover glass.
   a. Are the fibers all of the same size?
   b. Look for the alternate dark and

light stripes across the muscle. This appearance gives the name **striped muscle.**

c. Look for the broken places in the fibers. Can you distinguish an almost transparent sheath which covers the fiber, the **sarcolemma?**

2. Allow the preparation to stand for twenty or thirty minutes, then examine again. In the mean time, add a little salt solution to keep the muscle from drying. What change has taken place?
3. Remove the hard shell from the large part of the leg of a grasshopper, or better, a water beetle, tear out a little of the muscle, tease it out in salt solution, as before, and examine for striated muscle. Compare it with that of the frog. Try muscles from other animals.
4. Make accurate drawings showing the minute structure of muscle.
5. If it is desired to make permanent slides of striped muscular fibers, place some muscle that has been hardened in alcohol or formalin in borax carmine for twenty four hours, wash in water, tease in glycerine and mount in glycerine or glycerine jelly. The value of the preparations will depend on how carefully the muscle is teased.
6. If the laboratory is fitted with paraffin apparatus and a microtome both longitudinal and cross sections of muscle should be made and examined. See appendix for methods. Directions for a more detailed study of the minute

structure of striped muscle will be found in **30**, 193-199.

UNSTRIATED MUSCLE.

MATERIALS. Get from the butcher a piece of the intestine or gullet three or four days in advance of the lesson and put it in a solution of bichromate of potash (one part to ten of water). Cut a longitudinal strip from the intestine and remove from both the inner and outer sides as much of the tissue as you can.

1. Fray out with needles a small portion of the remaining muscle, on a glass slip, mount in water and look for unstriated fibers.
   a. Can you make out the shape of the cells? Look in your text-book for figures of these cells and verify the figures.
2. Stain the preparation by allowing a drop of hæmatoxylin or hæmalum to run under the cover glass.
   a. Do you see a nucleus in any of the cells?
3. Make an accurate drawing of an unstriated muscle cell.
4. Cut sections of a piece of hardened intestine that has been imbedded in paraffin, stain in hæmatoxylin, mount in Canada balsam and observe the unstriated muscular tissue which is found in the walls. These preparations are permanent and can be used when the study of the intestine is reached.

CARDIAC MUSCLE.

MATERIALS. Farrant's solution; some fresh heart tissue; 20 per cent. nitric acid or 2 per

cent. potassium bichromate; picro-carmine.

1. Place some very small pieces of the fresh heart muscle in the 20 per cent. nitric acid for two days or in the 2 per cent. potassium bichromate solution for the same time, then tease on a slide in Farrant's solution and examine. Notice:
   a. That the cross striations are present but not so marked as in true striated muscle.
   b. The shape of the fibers, which are short and thick with branching processes that meet similar processes from neighboring cells.
2. Tease in glycerine a piece of heart muscle that was put fresh into picro-carmine and has been standing in the same for several days.
   a. Notice the well defined nucleus.

PHYSIOLOGY OF MUSCLE.

1. EXPERIMENTS. Grasp the upper right arm with the left hand then alternately straighten and draw up the forearm. What change occurs in the biceps muscle? What change in the triceps, which is on the under side of the arm? When does the muscle seem most firm, in contracting or relaxing? What really takes place when a muscle contracts?
2. Grasp the forearm, then close the hand. Where is the muscle that closes the hand? Where is the muscle that opens the hand? Look on the back of the hand for the tendons that straighten the fingers.

3. Get from the butcher the foot of a chicken. Remove the skin and notice how the tendons are distributed to the various toes. Notice that some of the tendons pass through loops or, as they are called by some physiologists, **pulleys.** By pulling the various tendons determine which ones close, **flex**, the toes? Which ones straighten, **extend**, the toes?
4. Stand on the tiptoe and then determine which muscles become rigid in so doing. Locate the muscles that extend and flex the foot.
5. Locate the muscles which close the jaws.
6. Can you explain now why we feel so tired across the small of the back after standing for several hours?
7. Place a frog under a jar with a little ether, for a few minutes, then cut through the skin at the base of the skull, insert a wire into the skull cavity and destroy the brain.
    a. Pinch the frog's toe and notice that it moves.
    b. Touch the toe with a hot wire. What follows?
    c. Touch the skin on the leg or foot with some acid. Result?
    d. Allow the current from an induction coil to pass through the foot. Result?
8. In the experiments under **7**, the results might be attributed entirely to the nervous connection, but if a little curare be injected under the skin of the frog the motor nerve endings in the muscles will be paralyzed. Remove the skin

from the leg of the frog and try the experiments indicated under **7** and it will be found that the muscle is still contractile. A 1 per cent, watery solution of commercial curare should be used for the experiment and two or three drops of it may be injected under the skin with a hypodermic syringe or a pipette.

9. If the laboratory possesses a kymograph, induction coil and time marker, a nerve-muscle preparation should be made and experimented on. Since this apparatus will be found in but few schools where elementary work is done in Physiology, directions for its use will not be given here. Full directions for such work will be found in any of the following: **32**, 157; **33**; **10; 11; 12; 13; 15; 23; 35.**

10. Take a book in the hand and hold it out at right angles from the body until the arm becomes quite tired. Notice that the arm will gradually fall. Continued muscular action soon tires the muscle.

1. LEVERS. Place a book on the table and under one edge of it insert the end of a ruler. Lay your pencil under the ruler near the book then pull down on the free end of the ruler. The ruler here acts as a lever of the first class. The pencil is the point of support or the **fulcrum,** the book is the **weight** and the hand the **power.** Notice that the fulcrum is between the power and the weight.

Allow the head to drop forward then lift it up. Where is the fulcrum, the power, the weight?

The power arm of a lever multiplied by the power is equal to the weight arm multiplied by the weight, or written as a formula, **PAxP=WAxW.** If any three are given the other can easily be found. How much can a man lift with a lever of the first class if he weighs 150 pounds and the **PA** of the lever is 10 feet and the **WA** 5 feet? Draw a diagram of this lever in your note book and show the result.

2 Experiment again with the book and the ruler but this time push the ruler under until the end projects on the other side of the book. Lift up on the long end of the ruler and you have a lever of the second class. The table under the stationary end of the ruler is the fulcrum, the book, the weight and the hand the power. Draw a diagram of the levers and solve the following problems: In a lever of the second class, how much can a man lifting 150 pounds raise, if the bar is 15 feet long and the weight 5 feet from the fulcrum? Estimate the length of your foot, the distance from the ankle or astragulus bone, where the weight rests, to the heel, where the tendon of Achilles fastens, then determine how much power is exerted on the tendon of Achilles in lifting the body on one tiptoe.

3. Lay your ruler on the table and on one end of it place a book. Hold the other end down with one hand and with the other hand lift up on the ruler in the middle. You have now a lever of the third class. Supposing that in

throwing hay on a wagon a man should hold the upper end of the pitchfork handle stationary in his right hand and grasp the fork handle with the left hand two and one-half feet below the upper end, that the length of the fork handle is 8½ feet and that the man can exert a force of 50 pounds with his left arm. what is the weight of the hay which he can just lift on the wagon? If he loses in power in what may he gain?

Estimate the length of your fore arm from the palm of the hand to the elbow and the distance from the elbow to where the tendon of the biceps muscle joins the radius bone. Place the elbow against the body then determine by experiment how many pounds you can lift with your hand. From the above data determine how much work the biceps muscle must do to lift the weight.

Locate several third class levers in the body. What are the advantages of a third class lever? What are the disadvantages?

DIGESTIVE ORGANS, FOODS AND DIGESTION.

ALIMENTARY CANAL. **25**, 264; **15**, 200. **12**; **11**; **24**.

1a. What it is. **5**, 194.
2a. Complexity. **3**, 328.
3a. Development of. **36.**
4a. Lining of.
  1b. Nature of mucous membrane and mucus.
5a. Parts of.
  1b. Glands, in general. **2**, 106-109; **6**, 121; **9**, 140; **25**, 249.
    1c. Forms of. **3**, 284.
    2c. Secretion. **15**, 319; **10**, 152.
      1d. Physical explanation. **3**, 286.
      2d. Chemical explanation. **3**, 287.
  2b. Mouth. **6**, 122; **13**, 237.
    1c. Parts.
      1d. The teeth. **2**, 112; **3**, 329; **5**, 199; **6**, 123; **13**, 260.
        1e. The gums.
        2e. Development of. **18**, 899; **36**; **13**, 260.
        3e. Sets of teeth.
          1f. Number in each set.
          2f. Why is the milk set necessary?
          3f. Name and locate the different kinds of permanent teeth. **2**, 112.
        4e. Structure of a tooth. **2**, 113; **3**, 331.
          1f. Gross.

2f. Minute.
1g. Enamel.
2g. Cement.
3g. Dentine.
4g. Pulp.
5e. Compare the human teeth with those of the cow, rabbit, cat and dog. **15**, 304.
6e. Hygiene of teeth. **2**, 114.
1f. What causes teeth to decay?
2f. How does the dentist fill a tooth?
3f. What things are injurious to teeth?
4f. What advice should be given to children?
2d. The tongue. **2**, 115; **3**, 332; **13**, 264.
1e. Location and shape of the organ.
2e. Of what kind of tissue composed?
3e. The papillæ. **3**, 333.
1f. Circumvallate.
1g. Location and description.
2f. Fungiform.
1g. Location and description.
3f. Filiform.
1g. Location and description.
2g. Compare with those of the cat. **3**, 334.
4f. Physiology of the papillæ.
4e. Taste buds. **3**, 334.
5e. What is a "furred" tongue? **2**, 117; **3**, 334.
1f. Indication.
3d. Salivary glands. **2**, 117; **3**, 334; **5**, 203; **13**, 241; **14**, 317, 324.

1e. Name and location of each.
1f. Their secretion.
4d. The fauces. **2**, 119; **3**, 335.
1e. Bounded by what?
2e. Pillars of fauces.
1f. Tonsils.
1g. Diseases of. **2**, 119.
5d. Pharynx. **2**, 117; **3**, 335; **6**, 128.
1e. Location and description.
2e. Openings.
3e. Epiglottis.
3b. Oesophagus. **2**, 120; **3**, 336; **6**, 128.
1d. Location.
2d. Structure (coats).
1e. Describe each carefully.
3d. Length.
4d. Physiology of.
4b. Stomach. **2**, 120; **3**, 336; **5**, 213; **6**, 129; **13** 273, 284; **12**, 319.
1d. Location.
2d. Shape.
3d. Size.
4d. Openings.
5d. Great omentum. **3**, 336.
6d. Structure (coats). **3**, 337.
1e. Outer serous coat.
2e. Muscular coat of three layers. **2**, 122.
3e. Submucous coat.
4e. Mucous coat.
1f. Folds of.
2f. Gastric glands.
7d. The pylorus.. **3**, 338.
8d. Blood vessels of the stomach.. **3**, 337.

9d. Nerves of the stomach. **3**, 337.
5b. Small intestine. **2**, 123; **3**, 399; **6**, 134.
1d. Size at the pylorus.
2d. Length.
3d. Arbitrary divisions.
1e. Duodenum.
2e. Jejunum.
3e. Ileum.
4d. Structure.
1e. Coats. **2**, 123.
1f. Compare the serous, muscular and submucous coats with those of the gullet and stomach.
2f. Mucous. **3**, 339.
1g. The valvulæ conniventes. **2**, 123.
1h. Where located.
2h. Use.
2g. The villi. **2**, 124; **3**, 340.
1h. Where most numerous?
2h. Minute structure.
3h. Function.
5d. Glands of.
1e. Those in the walls.
1f. Crypts of Lieberkuehn. **2**, 125; **3**, 341.
1g. Locate.
2g. Function.
2f. Brunner's glands. **3**, 341.
2e. Those opening into the duodenum from outside the walls.
1f. Pancreas. **3**, 346; **6**, 141.
1g. Kind of gland.
2g. Size and location.
3g. Secretion.

2f. The liver. **2**, 128; **3**, 344; **6**, 137; **13**, 309; **14**, 217.
1g. Location.
2g. Size.
3g. Structure.
4g. Blood vessels.
5g. Bile sac and duct.
6g. Secretion.
6d. The mesenteries. **14**, 189.
6b. Large intestine. **2**, 155; **3**, 342; **6**, 136.
1d. Position.
2d. Length.
3d. Diameter.
4d. Divisions.
1e. Cæcum.
1f. Vermiform appendix. **2**, 127.
1g. Explanation of.
2g. Disease of.
2e. Colon.
3e. Rectum.
5d. Structure (coats).
6d. Ileo-colic valve. **3**, 342.
1e. Function.
7b. Ductless glands more or less closely connected with the alimentary canal.
1d. The spleen. **5**, 356; **2**, 163, 299; **10**, 260, 272; **14**, 225.
1e. Location.
2e. Structure.
3e. Probable function.
2d. Thyroid gland. **3**, 357; **2**, 299-300; **14**, 228.
1e. Location.

2e. Probable function.
3e. Disease of.
3d. Thymus. **3**, 358; **2**, 130; **14**, 229.
1e. Location.

FOODS. **7**, 107-155; **25**, 308; **15**, 290; **10**, 213; **38**; **14**, 153; **11**; **12**, 24, 1.

1a. Introduction.
1b. Losses going on constantly in the body. **3**, 299; **6**, 97; **14**, 155.
1c. In food matter.
2c. In energy. **3**, 301.
1d. What is the source of this energy? **2**, 74; **14**, 160.
2d. What is conservation of energy? **2**, 74; **3**, 302.
1e. Illustrate.
2b. Why we need food. **2**, 115; **6**, 97.
1c. To furnish energy.
2c. To furnish heat.
1d. Temperature of a healthy human body. **2**, 76; **3**, 477; **9**, 136; **25**, 376; **10**, 575.
2d. What is meant by warm and cold blooded animals? **3**, 477.
3d. What is meant by oxidation in the body? **2**, 78; **3**, 309.
3b. How can oxygen be considered a food? **2**, 81.
4b. What is meant by nutrition, in its broadest sense? **3**, 451-476; **25**, 365.
2a. What is a food? **2**, 88; **3**, 317.
3a. What must a food contain? **3**, 313-314; **2**, 88.
1b. Importance of albumens. **2**, 89; **3**, 319.

4a. Relation of plants and animals to each other. **2**, 90.
1b. Show that plants build up and animals tear down.
5a. What is a non-oxidizable food? **2**, 90; **3**, 316.
6a. Kinds of foods or "alimentary principles". **5**, 167; **6**, 99; **9**, 144; **14**, 155.
1b. Albumens or proteids. **3**, 319.
1c. Composition.
2c. Common forms. **2**, 92.
3c. Value as foods. **2**, 94; **10**, 282.
1d. Energy producers.
2d. Heat producers. **2**, 95.
4c. What are the albuminoids? **3**, 319.
2b. Hydrocarbons or fats and oils. **2**, 94; **3**, 319.
1c. Composition.
2c. Common examples.
3c. Value of as foods. **10**, 282.
1d. As energy producers.
2d. Heat producers. **2**, 95.
4c. Source of our supply.
3b. Carbohydrates or starches and sugars. **3**, 319; **2**, 94.
1c. Composition.
2c. Common forms.
3c. Value as foods. **10**, 292.
1d. As energy producers.
2d. As heat producers. **2**, 95.
4c. Source of our supply.
4b. Inorganic foods. **2**, 96; **3**, 320.
1c. Water.
1d. Use.
2c. Salts.

1d. Kinds.
2d. Value.

7a. Importance of the following as foods: pork, beef, corn, wheat, beans, peas, eggs, milk, cheese, butter, fruits. **3**, 321-323; **6**, 103.
1b. Some parasites in pork.
1c. Tape worm. **20**.
2c. Trichina. **2**, 97.
1d. Life history.
3c. How should pork always be cooked?

8a. Alcohol, tea and coffee as foods. **2**, 98-99; **3**, 323; **5**, 174; **6**, 113, 159.

9a. Why do we need a mixed diet? **3**, 325; **2**, 101.

DIGESTION. **9**, 152-168; **25**, 327; **15**, 290; **17**, 129; **12**; **11**; **24**.

1a. Object of. **2**, 131; **3**, 361; **6**, 119; **9**, 143.

2a. In the mouth. **6**, 122; **7**, 51-65; **17**, 151; **10**, 220; **14**, 166.
1b. The saliva. **2**, 131; **3**, 361-362; **14**, 169; **12**, 302.
1c. Nature of.
1d. Chemical composition.
2c. Digestive action. **2**, 131; **13**, 254.
3c. Physical action.
2b. Absorption in the mouth. **6**, 145.
3b. Describe the process of swallowing (deglutition). **2**, 131; **6**, 128; **17**, 134; **13**, 266.

3a. In the stomach. **6**, 132; **7**, 66-77; **17**, 169; **10**, 225; **14**, 176.
1b. Gastric juice. **2**, 135; **3**, 365; **13**, 289; **14**, 182; **12**, 307.
1c. Chemical composition.

1d. Pepsin.
1e. Digestive action. **2**, 135.
2d. Other compounds.
1e. Digestive action of each.
2b. Condition of the food in the stomach. **2**, 136.
3b. Absorption in the stomach. **2**, 144; **6**, 145.
4a. In the small intestine. **7**, 79-88; **17**, 182; **14**, 190.
1b. Digestive fluids. **3**, 368.
1c. Pancreatic juice. **2**, 137; **6**, 142; **13**, 303; **14**, 184.
1d. Chemical composition. **2**, 137-138; **3**, 369.
1e. Digestive action of each compound.
2c. Bile. **3**, 370; **6**, 138; **17**, 189; **13**, 315, 324; **10**, 260; **14**, 187.
1d. Chemical composition.
2d. Digestive action of. **2**, 139; **3**, 370; **13**, 334; **15**, 313.
3c. Other intestinal juices. **2**, 140; **3**, 371.
1d. Effect in digestion. **2**, 141.
2b. Condition of the food in the small intestine.
3b. Absorption in the small intestine. **2**, 144; **3**, 340.
1c. Describe the lacteals. **2**, 124, 145; **6**, 145.
2c. The thoracic duct. **2**, 161; **6**, 146.
5a. The large intestine. **13**, 345.
1b. Condition of the food matter here. **6**, 144.
2b. Absorption in. **2**, 146.
6a. Movements of the alimentary canal. **3**, 378; **15**, 331; **10**, 307; **14**, 203.
7a. What is dialysis or osmosis?
1b. Its relation to absorption. **17**, 209; **13**, 353; **10**, 250; **14**, 194.

8a. What is assimilitaon? **7**, 89-97.
9a. Hygiene of digestion. **5**, 230.
1b. Dyspepsia. **2**, 142.
1c. Causes.
2c. Forms of.
1d. Palpitation of the heart.
2b. Cooking.
1c. Object.
2c. Methods.

LABORATORY EXERCISES.

*)THE DISSECTION OF A MAMMAL.

MATERIALS. A cat or rabbit or even a rat; a pair of forceps; a sharp knife and a bottle of chloroform or sulphuric ether.

1. Place the animal in a tight box or under a large battery jar, then insert some cotton which has been saturated with the chloroform or ether. When the animal is dead, which will be in eight or ten minutes, remove it to a board with a nail in each corner, to which the limbs can be tied. Notice the following **external features:**

a. The main parts of the body, as **head, trunk** and **limbs.**

b. Compare the fore limbs with those of your own body as to bones, joints and movements. Do the same with the hind limbs.

*) The student's attention is directed to a number of organs that do not belong to the alimentary canal because it is impracticable to have a different animal for each set of organs.

c. The shape of the chest as compared with that of the human body. Why so different?

d. The hair which covers the animal. Can you notice more than one kind of hair?

e. The long stiff hairs or **whiskers** about the mouth. What is their use?

f. Are any parts not covered with hair?

g. Shape and texture of the external ears.

h. What movements have the claws? How is the sole of the foot covered? How well is the foot adapted to the habits of the animal?

2. Open the **mouth** of the animal and notice:

a. The **teeth.** Compare each group with those of your own mouth.

b. The **gums.**

c. Draw out the tongue and observe the **papillæ** on the upper surface. In the cat the **filiform** papillæ are stiff and sharp. Use? Look for the **circumvallate** papillæ on the back portion of the tongue. In the rabbit two patches, the **papillæ foliatæ,** on the sides of the back portion of the tongue, contain numerous **taste buds.**

d. The roof of the mouth, formed by the hard palate in front and the soft palate behind. Find the **uvula,**

a small projection hanging down near the back of the mouth cavity.

3. Cut just through the skin along the middle line of the chest and abdomen, loosen it from the body and pin the cut edges back. Notice the muscles of the chest and abdomen and the directions in which they run. Carefully cut through the abdominal wall from the tip of the sternum downwards. Make a transverse cut on each side and pin back the four flaps. Observe:
   a. The coiled intestine and distinguish both large and small intestines.
   b. In the upper portion of the cavity, the large dark colored **liver,** under which lies the **stomach.**
   c. Notice the partition which separates the thoracic and abdominal cavities, the **diaphragm.** Of what kind of tissues is it composed?
4. Lift up the stomach and find the **œsophagus** where it passes through the diaphragm.
5. Tie the œsophagus in two places here and cut it off between the ligatures. Lift up the stomach and notice its shape. Make a drawing of it, showing where the œsophagus enters and where the intestine leaves.
6. On the right side and more or less loosely connected with the stomach notice a long brown body, the **spleen.**
7. Along the first part of the small intestine distinguish a pinkish gland, the **pancreas.**
8. Examine the liver more carefully and see how

many lobes it has. Find the **gall sac.** Can you trace the bile duct to where it enters the intestine? Look for the blood vessels of the liver.

9. The membrane and blood vessels which are fastened all along the intestine form the **mesentery.** Notice how it is fastened.

10. Trace the small intestine to where it enters the large intestine. Notice the side branch, the **cæcum.** Does it have an appendix? The caecum is very large in the rabbit, smaller in the cat.

11. Trace the large intestine and notice its position.

12. Lift up the intestines and observe about the middle of the back and on each side of the middle two dark bodies, more or less buried in fat, the **kidneys.** Find a tube, the **ureter,** leading from each one. Trace the tubes to where they enter the yellowish colored sac, the **bladder,** which is located in the posterior portion of the abdominal cavity. Notice the blood vessels which lead to and from the kidneys.

13. Tie the intestine in two places about six inches from the stomach, cut it off and carefully slit open both stomach and intestine under running water. In the stomach notice:
    - *a.* The openings, **cardiac** and **pyloric.**
    - *b.* The nature of the mucous membrane lining the stomach.
    - *c.* The mucous membrane of the intestine arranged in **folds** and these covered with **villi.**

14. Notice the lining of the abdominal cavity, the

peritoneum. How does it feel to the touch?

15. Grasp the diaphragm with a pair of forceps and pull down on it. Can you hear air rush in at the mouth?
16. Observe the lungs through the diaphragm and note their position. With a knife point prick a hole in one side of the diaphragm. Why did the lung collapse?
17. Open up the chest cavity by cutting in a median line from the lower point of the sternum to the upper end of the cavity. Pin back the walls and notice:
    a. The lining.
    b. The blood vessels along each rib.
    c. The general arrangement of the lungs and heart.
    d. The œsophagus.
18. Insert a tube through the mouth into the windpipe and blow up the lungs. Notice:
    a. The lobes of the lungs.
    b. How the lungs fit about the heart.
19. Examine the heart as to position and shape. Slit open the membrane covering it, the **pericardium.** Observe the inner surface of this membrane. Did any liquid escape when the membrane was cut? Does the pericardium fit the heart closely?
20. Cut the skin along the under side of the neck and carefully remove it from one side of the head and neck. Trace the œsophagus and trachea to the pharynx. Notice the rings in the trachea.
21. Look for the salivary glands, the largest just

under the ear. Remove this gland and harden it in Perenyi's fluid (see appendix).

THE HUMAN ALIMENTARY CANAL.

THE MOUTH. With a mirror before you open the mouth and examine it.

1. Distinguish the **fungiform papillæ,** little red dots scattered over the surface of the tongue.
2. Distinguish the very numerous **filiform papillæ** that cover all the surface between the fungiform papillæ. Allow a drop of vinegar to fall on the tongue. What effect on the papillæ?
3. Press down on the back portion of the tongue with a pencil or other object and notice the very large **circumvallate papillæ.**
4. Try tasting salt on different portions of the tongue. Where can you taste it best? Try sugar.
5. Count your teeth and distinguish the different kinds. Have you any "wisdom" teeth?
6. Notice the roof of the mouth and the uvula.
7. Imbed in paraffin a piece of the hardened salivary gland referred to under materials, cut sections, mount and examine. Notice the typical gland structure of alveoli and ducts.
8. Examine a longitudinal section of a tooth, if such a section can be had, and notice the following:
   - *a.* The **enamel.** Has it any structure?
   - *b.* The **dentine.** Structure?
   - *c.* The **cement.**

d. The **pulp cavity.**

e. Make a careful drawing showing the structure of the tooth.

THE OESOPHAGUS, STOMACH AND INTESTINE.

1. Make sections by the paraffin method of the hardened œsophagus and distinguish under the microscope the following coats:
   a. The outer **serous** coat.
   b. Under this a **muscular** coat of two layers, one **circular**, the other **longitudinal.**
   c. Next a **submucous** coat.
   d. An inner **mucous** coat.
2. Make sections of a piece of stomach and examine in the same way that you did the œsophagus. What likenesses and differences do you note?
3. Make sections of the small intestine and note the following:
   a. The outer **serous** coat.
   b. The **muscular** coat. Compare with that of the stomach and œsophagus.
   c. The inner **mucous** coat. On this notice the projecting **villi.**
4. Section a small piece of liver, stain in hæmatoxylin and note the rather large **lobules,** and in these the liver cells. If a piece of liver from an injected animal can be had the results will be much better.

FOODS.

MATERIALS. A piece of beef steak; common vegetables; an egg; nitric acid; test tubes; am-

monia; caustic soda; copper sulphate; fresh milk; iodine solution; several common grains and seeds; glucose; sulphuric acid; Fehling's solution (appendix); raisins; flour; sodium carbonate; common sugar; sweet oil; benzine.

1. WATER IN FOODS. Take a small piece of meat, weigh it, then put it over a flame or in a current of air and keep it there until perfectly dry. How much water evaporated? The piece must be small or the drying will be very slow and will not be complete.
2. Try pieces of cabbage, potato and other vegetables in the same way.

1. ALBUMENS OR PROTEIDS. Shake up some white of egg thoroughly in water, then filter through cloth, add strong nitric acid to a portion of the filtered liquid in a test tube. Heat and notice the **yellow** color. Allow the preparation to cool, then add a little ammonia. Look for an **orange** color. This is a common test for albumin.
2. To another portion of the egg solution add some strong caustic soda. To this add two or three drops of a 1 per cent. solution of copper sulphate. Warm the tube gently and notice the **violet** color. This is a second test for albumin.
3. Put some white of egg in a test tube, place in the same a thermometer, then heat gently and watch for the coagulation point.
4. Test macaroni, a product of flour, by making a solution and then applying test number 1. Test a little of the scum from boiled milk in

the same manner. For further experiments on proteids see **32**, 1–14.

1. CARBOHYDRATES OR STARCHES AND SUGARS. Scrape a little potato on a glass slip, cover with a cover glass, then examine with the high power microscope. Note the shape of the grains. Let a drop of iodine solution run under the edge of the cover, then notice the **blue** color of each grain.
2. Scrape a little powder from each of the following: Beans, peas, corn, rice and oats, and test for starch. Test fruits and vegetables.
3. Scrape some potato in cold water, allow the preparation to stand, then with a pipette take a little of the clear water and test it with iodine for starch. Does starch dissolve in cold water?
4. Shake the vessel used in the last experiment, pour some of the contents into a test tube and boil. Does the starch dissolve in hot water?
5. Taste glucose. How does it compare with good syrup in sweetness?
   - *a.* Put some glucose in a test tube, add a little strong sulphuric acid and heat. The contents of the tube should darken slowly.
   - *b.* Add a little Fehling's solution to some glucose and boil. Notice the **yellowish-red precipitate.**

NOTE. If Fehling's solution is not at hand the test may be made by using the caustic soda and copper sulphate solutions mentioned under experiment number 2 for albumin. More of the copper solution should be added and the preparation should be boiled until a yellowish or red precipitate is formed.

c. Chop up some raisins, soak in water and test the water for grape sugar.

6. Make a thin starch solution, add to some of it a few drops of a 20 per cent. solution of sulphuric acid and boil until clear. Add a solution of sodium carbonate until the acid has been neutralized, then test for glucose. The starch has been changed to sugar (glucose).
7. Make a syrup of common sugar, add some strong sulphuric acid and heat, if necessary. Result?
8. Test a number of foods for sugar, using Fehling's test. Add the solution to the substance to be tested, then boil. Try milk and flour.

1. FATS AND OILS. Put a few drops of sweet oil in a test tube, add some benzine and shake. What result? Put a drop of the solution on some writing paper and allow it to dry. Is a greasy stain left on the paper? Try to shake up some oil with water. Result?
2. To some sweet oil in a test tube add some caustic soda solution, boil until a soap is formed.
3. Shake some sweet oil with some white of egg solution and notice that an **emulsion** is formed.
4. Test several foods for oils by using the benzine and greasy spot test. Milk and flour should be so tested.

1. MINERAL SUBSTANCES. Evaporate some milk to dryness, then burn what is left to ashes on a clean piece of metal. Try other things in the

same manner. The ash is the mineral substance.

DIGESTION.

MATERIALS. Litmus paper, red and blue; starch paste; Fehling's solution; fibrin obtained by whipping freshly drawn blood; pepsin; .2 per cent. hydrochloric acid; water bath; sweet milk; commercial rennet; pancreatin solution; sodium carbonate; olive oil; bile; filter paper; some parchment or bladder; salt; silver nitrate; an egg; sealing wax; glass tube.

1 With pieces of litmus paper test the saliva to determine whether or not it is alkaline or acid.

2. To some starch paste solution in a test tube add a little saliva, allow the preparation to stand for half an hour, then test for grape sugar with Fehling's solution.

3. Prepare three test tubes as follows: In one tube place a little boiled fibrin over which has been poured some pepsin solution made from the commercial pepsin that can be obtained at any drug store. In a second tube put some of the boiled fibrin and the .2 per cent. solution of hydrochloric acid. In the third tube put some boiled fibrin and add some pepsin solution and some of the .2 per cent. solution of hydrochloric acid. Place all three tubes in a water bath or other warm place. The tubes should stand for several hours, even over night if the temperature can be kept uniform. What effect has the pepsin on the material in the first tube? Has the hydrochloric acid any digestive effect?

What has happened to the material in the third tube?

*) Pepsin and hydrochloric acid are always present in a healthy stomach. If fibrin cannot be had for the above experiment, use finely chopped white of a hard boiled egg.

4. Put some sweet milk in a test tube, then add a few drops of commercial **rennet.** Keep the preparation at a temperature of 98 degrees for a few minutes and notice that the milk becomes solid. **Rennin** is one of the contituents of gastric juice.

5. Add to a little starch paste in a test tube a few drops of a pancreatin solution. Keep in a warm place for a short time, then test with Fehling's solution.

6. Prepare two test tubes as follows: In the first, place a little fibrin, a small quantity of pancreatin solution and a larger quantity of a 1 per cent. solution of sodium carbonate. Prepare the second tube in the same way except instead of the sodium carbonate solution use a .2 per cent. solution of hydrochloric acid. Place the tubes in a water bath, where they

*) Those who prefer to do so may prepare artificial gastric juice in the following manner: Procure a pig's stomach, wash it out, then remove the mucous membrane from the cardiac end, dry it between sheets of paper, then pulverize it and cover well with strong glycerine. Shake the preparation occasionally and after several days filter through cloth. The glycerine will have dissolved the pepsin. Before using, add several volumes of .2 per cent. hydrochloric acid. A pancreatin solution may be prepared by soaking the pancreas of a pig in water for several hours and then chopping it up and treating with glycerine as was indicated for pepsin.

should remain for several hours at a temperature of 98 degrees Fahrenheit. Result?

7. Shake some pancreatin solution in a tube with a small quantity of olive oil, to which has been added a little 1 per cent. sodium carbonate solution. Is an emulsion formed?

8. Get some fresh bile from the butcher and test it with litmus paper to determine whether it is alkaline or acid.

9. Take two funnels of the same size and place in each a piece of filter paper. Moisten the paper in one funnel with bile and the other with water. Pour into each funnel a few spoonfuls of olive oil and set aside for several hours. Through which paper does the oil pass most readily? What seems to be the effect of bile on filtration?

1. *) OSMOSIS OR DIALYSIS. Tie a piece of bladder or parchment tightly over the end of a lamp chimney and in the lamp chimney put some water to which a little salt has been added. Place the lamp chimney with the salt water into a vessel of pure water, and, after a few minutes, test the pure water by adding a few drops of silver nitrate to a small quantity of it. A white precipitate is formed, showing that some of the salt has passed through the animal membrane. The solutions should be tested before the experiment to insure that they are pure.

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*) Since there is more or less absorption along the alimintary canal, it is well to make the experiments on dialysis here.

2. Chip off the shell from a spot at the larger end of an egg but do not break the membrane beneath the shell. At the other end of the egg make a small hole through both shell and membrane and over this fasten with sealing wax the end of a glass tube, four or five inches long. Place the egg with its larger end down in a glass or bottle of water, whose mouth is just large enough to prevent the egg from passing in. Notice that after a few hours the contents of the shell begin to rise in the tube. Why? Does any of the egg pass out into the water? Undigested albumen will not dialyze to any extent.

CIRCULATORY TISSUES.

CIRCULATORY TISSUES.

1a. External medium. **3**, 40;
  1b. What?
2a. Internal medium. **3**, 40.
  1b. Necessity of in our bodies. **2**, 147.
    1c. Carrying food.
    2c. Removing wastes, **2**, 148.
  2b. The blood. **3**. 41; **5**, 48; **6**, 170; **25**, 49; **13**, 1–57; **10**, 331; **14**; **17**; **11**; **12**.
    1c. Quantity and general distribution of. **2**, 148; **3**, 61, 211; **25**, 50.
      1d. Where not found?
    2c. Composition. **2**, 148; **3**, 44; **5**, 94.
      1d. Plasma.
      2d. Corpuscles. **2**, 149; **3**, 44; **6**, 171.
        1e. Red. **25**, 51.
          1f. Shape.
          2f. Size.
          3f. Abundance of.
          4f. Color.
          5f. Structure.
            1g. Hæmaglobin. **2**, 150.
              1h. Blood crystals. **3**, 47; **25**, 56.
            2g. Stroma.
          6f. Consistency.
          7f. Arterial and venous blood.
          8f. Origin of. **3**, 61; **25**, 59.

2e. Colorless. **2**, 150; **3**, 47; **25**, 62.
1f. Size as compared with the red.
2f. Number as compared with the red.
3f. Structure.
1g. Nucleus.
2g. No cell wall.
4f. Movements.
5f. Physiology.
3e. Blood plaques. **3**, 49; **25**, 65.
1f. Compare with the other corpuscles.
4e. Blood of other animals. **3**, 49.
3c. Coagulation. **2**, 152; **3**, 51; **6**, 173; **25**, 67.
1d. Stages of.
1e. Gelatinization.
2e. Concave surface.
3e. Shrinking of the clot.
4e. Buffy coat.
2d. Cause of. **2**, 152; **3**, 51;
1e. Fibrin.
1f. Why form? **3**, 53;
2f. From whence come? **3**, 54–56.
1g. Composition.
1h. Fibrinogen.
2h. Fibrin ferment.
3h. Salts.
3d. Coagulation in other animals.
3b. The lymph. **2**, 157; **3**, 42; **5**, 98; **10**, 362, 437; **14**; **11**; **11**; **12**.
1c. Composition. **2**, 162; **3**, 49.
1d. Watery liquid.
2d. Corpuscles.
1e. How like white blood corpuscles?
2e. Physiology of.

2c. Where found?
3c. How renewed? **2**, 158.
4c. Lymph vessels.
1d. Ordinary form.
2d. Lacteals. **2**, 161.
3d. Thoracic duct,
4b. Heart and blood vessels. **2**, 163; **5**, 59.
1c. General flow of the blood in life. **3**, 211.
2c. The heart. **2**, 165–169; **6**, 176; **25**, 150; **13**, 57–89; **15**, 217.
1d. Position. **3**, 213.
2d. Membranes. **3**, 213.
1e. Outside.
1f. Lining.
1g. Liquid bathing.
2g. Disease of. **3**, 213.
2e. Inside.
3d. Main divisions of. **3**, 214.
1e. Nature of the walls of each cavity,
4d. Auriculo-ventricular valves. **3**, 217.
1e. Chordæ tendineæ.
2e. Papillary muscles.
1f. Physiology of. **2**, 182; **3**, 230.
5d. Semilunar valves. **3**, 217.
1e. Location.
2e. Use.
6d. Nourishment of the heart.
1e. Blood vessels concerned in. **5**, 86.
5b. Arterial system. **3**, 218; **6**, 180; **13**, 106.
1c. Structure of the arteries. **2**, 172; **3**, 225; **5**, 77; **25**, 159.
1d. Physiology of this structure. **2**, 190.
2c. Trace the main arteries of the body. **2**, 169.

6b. The venous system. **2**, 173, **6**, 182, **13**, 158,
1c. Structure of the veins. **3**, 226,
1d. The valves. **2**, 174,
2c. Difference in structure of veins and arteries.
3c. How distinguish the two in butchered animals?
4c. Trace the chief veins of the body.
7b. The capillaries. **3**, 220; **6**, 183; **15**, 281.
1c. Structure.
2c. Location.
3c. Physiology of.
1d. Osmosis.
4c. Rate of blood flow in. **2**, 187; **5**, 78, 84.
8b. What is the pulmonary circulation? **3**, 223; **10**, 395.
9b. What is the systemic circulation?
10b. What is the portal circulation? **2**, 176, **3**, 223; **6**, 186.
11b. Beats of the heart. **2**, 180; **3**, 227; **5**, 75; **6**, 186; **25**, 161.
1c. Systole.
2c. Diastole.
3c. Pause.
4c. What change in the heart's shape when it beats? **3**, 227.
5c. Cardiac impulse or heart beat. **2**, 180; **3**, 228.
1d. Full explanation.
6c. Events occuring during a cardiac cycle. **2**, 181; **3**, 228.
7c. Sounds of the heart. **2**, 183; **10**, 410.
1d. Cause of each.
12b. Use of the auricles. **2**, 183; **3**, 231; **10**, 426.

13b. Work of the heart. **2**, 148; **3**, 233; **10**, 396.
14b. Nerves of the heart and blood vessels. **2**; 185; **3**, 253–273; **5**, 90; **25**, 173; **13**, 89; **15**, 261; **10**, 440; **11**; **12**.
15b. Flow of the blood outside the heart. **3**, 234,
1c. Axial current. **3**, 235.
2c. Inert layer.
3c. Internal friction. **3**, 236.
4c. Arterial pressure. **3**, 240–246; **10**, 377, 383.
1d. Things that may influence.
1e. Rate of heart beat.
2e. Force of the heart beat.
3e. Peripheral resistance, **2**, 187.
5c. Rate of blood flow. **3**, 248; **10**, 390.
6c. The pulse. **2**, 186; **3**, 246; **13**, 112; **10**, 385, 431.
1d. Cause.
2d. Rate of travel.
3d. May indicate what? **2**, 186.
4d. Why not found in the veins? **2**, 189.
16b. Secondary causes of circulation.
1c. Gravity.
2c. Transient pressure on the veins.
3c. Breathing.
17b. Proofs of the circulation. **3**, 251.
18b. Hygiene.
1c. Taking cold. **2**, 191.
2c. Lack of coloring matter. **3**, 60.

LABORATORY EXERCISES.

THE BLOOD.

MATERIALS. A needle; normal salt solution; 1 per cent. acetic acid; a solution of magenta; a frog; iodine; Fehling's solution.

1. STRUCTURE OF THE HUMAN BLOOD. Draw a drop of blood from the little finger by inserting a needle under the skin at the base of the nail. Place the blood on a glass slip, add a little normal salt solution and apply a cover glass. With the low power observe the many small apparently spherical bodies, the **corpuscles.** What is their color?
2. With the high power observe the **red corpuscles.**
   a. What is their shape?
   b. Look for their arrangement in coin-like rows.
   c. Can you distinguish any outward coat or wall?
3. In the preparation just used, with the high power, look for the **white corpuscles.** They are slightly larger than the red and not so numerous. If not seen at first press on the cover glass with a needle while looking into the instrument. The white corpuscles remain stationary while the red ones move about.
   a. Are the white corpuscles all of the same shape?
   b. Number of white as compared with the red corpuscles.
   c. Do the white corpuscles seem to change

their shapes? Repeat the exercises outlined under motor tissues on page 43.

d. Can you observe any cell wall in these corpuscles?

4. Run a drop of 1 per cent. acetic acid under the cover glass of the preparation just used and notice:

a. That the protoplasm becomes transparent.

b. That the nucleus comes into view.

5. Run a drop of a weak solution of magenta under the cover of a fresh preparation. Notice that it stains the nucleus of the white corpuscles deep red and the protoplasm not so red.

6. Prepare another slide by mixing a little normal salt solution with a drop of blood before applying the cover glass. Let the preparation stand for fifteen or twenty minutes and then allow water to run under the cover until the corpuscles are nearly colorless. Examine with the high power for fine fibers of fibrin.

1. FROG'S BLOOD. Prepare a slide of Frog's blood and notice the red corpuscles.

a. What is their shape when seen flatwise?

b. Shape when seen edgewise?

c. The rather large nucleus.

2. Observe the white corpuscles, which are smaller than the red. What is their shape?

3. How do the corpuscles of the frog compare with those of man?

4. Stain the preparation with a little magenta and observe the effect.

1. COAGULATION. Take two bottles or jars to the slaughter house and fill them with fresh blood as it runs from some animal. Set one bottle aside where it can remain perfectly quiet until the blood has clotted.

   Mark this bottle number 1. With a doubled wire begin immediately to stir the blood in the second bottle, number 2, and continue to do so until the blood in bottle number 1 has coagulated. The bottles may now be carried to the laboratory but great care should be taken not to shake number 1. Observe bottle number 1.

   a. How did the blood appear just after it had clotted? What was its color? Was its surface concave? If so why?

   b. After the bottle has stood for some time notice that the clot grows smaller and that there is a layer of **serum** all around it. How can this be explained?

   c. Can you observe any difference in the serum at the top of the bottle and that at the bottom, or the so called **buffy coat?**

2. Pour some of the serum into a test tube and heat it. Does it coagulate? In this respect how does it compare with the white of egg when boiled.

3. Test the serum for starch by adding a few drops of iodine solution. Result?

4. Test for sugar by using Fehling's solution (page 72). Result?

5. Test for oils by the benzine and greasy

spot method (page 73).

6. Test serum for mineral substances in the same manner that you did milk (page 73). Result?

7. What is your conclusion as to the different kinds of food stuffs found in blood serum?

8. Examine bottle number 2. Has the blood coagulated? Lift the wire from the bottle and wash the corpuscles from the adhering fibrin.
   a. What is the color of the fibrin? Pull it to see what properties it possesses.
   b. Test the fibrin for albumin by the nitric acid and ammonia method (page 71). Result?
   c. Does the blood appear more red at the surface in bottle number 2 than below? Why? Shake some of the blood vigorously in a test tube. Does the shaking change the color? Why?

THE HEART AND BLOOD VESSELS,

MATERIALS. Pieces of hardened artery and vein; picro carmine solution; glass and rubber tubing. Get from the butcher the heart and lungs of some mammal, such as a pig or lamb, that have been removed from the animal in tact, care having been taken to cut neither the heart nor the lungs. These parts from larger animals, such as the cow, will answer but they are unwieldy and do not show the parts much better than those from smaller mammals.

1. Place the heart and lungs on a table before

you, dorsal side down, with the trachea towards you. Notice the position of the heart. Where is it located with reference to the lobes of the lungs? Inflate the lungs and notice how they fold around the heart. The lungs may be inflated by placing a tube in the trachea and then blowing into it with the mouth, or, better, if a hand or foot bellows be accessible, with that. How many lobes has each lung?

2. With the heart and lungs in the same position, look for the membrane which surrounds the heart, the **pericardium.**
   a. Slit open the pericardium. Is there any liquid inside it? What is this liquid?
   b. Notice the inside surface of the pericardium.
   c. Where is the pericardium largest? Why?
   b. Carefully trim away the pericardium and notice the **base** and **apex** of the heart.

3. Distinguish the right and left sides of the heart. Make out the **auricles** and **ventricles.** The left ventricle may easily be distinguished by feeling of the two and selecting the one which has the thickest walls.

4. Find the following blood vessels:
   a. The **aorta** whose cut end is plainly visible.
   b. The **pulmonary artery** which passes from the lung to the heart and is very short.
   c. The two **vena cavæ.** Notice their cut ends and verify the fact that one

is **ascending** and the other **descending.**

d. The **pulmonary veins.** They are short and must be looked for carefully.

5. Make a drawing of the heart in position and show all the parts that are visible.

6. Remove the heart from the lungs by cutting the blood vessels off as far away from the lungs as possible. Notice the two grooves running obliquely from the base to the apex of the heart. These lines mark the division between the two halves. Notice the blood vessels running in the grooves.

Make a cut across the middle of the right ventricle half way between the grooves, which divide the heart into right and left halves, and in a line parallel with the grooves. Cut lightly, just enough to sever the walls, being sure that you do not injure the valves and muscles inside the heart. Open the right ventricle from one end to the other but do not injure in any way the left ventricle. Observe:

a. The cone-like muscular projections inside the ventricle, the **papillary muscles.** How many are there?

b. The tendon-like cords, **chordæ tendineæ,** which lead away from the papillary muscles to the flaps above. How many groups of these chordæ tendineæ are there?

c. The thin flaps, **valves,** which hang down from the roof of the ventricle.

How many are there in the right ventricle? Their name? What kind of edges have these valves?

d. The distribution of the chordæ tendineæ. Do those from one papillary muscle all connect with the same valve? Is there any advantage in the way they are arranged?

e. Push the edges of the valves together and see if they close the opening between the auricle and the ventricle, the **auriculo ventricular aperture.**

7. Cut upwards between the edges of two of the valves and open the **right auricle.**

a. Compare the wall of the auricle with that of the ventricle.

b. Find the openings of the two **vena cavæ.** In what part of the auricle are they located?

c. Find the opening of the coronary vein in the back of the auricle. Run a broom straw into this vein and determine where it leads. What is its function?

8. Find the opening of the pulmonary artery in the upper portion of the right ventricle. Observe the three flaps, **semilunar valves,** which close it.

9. By cutting between two of the semilunar valves slit open the pulmonary artery lengthwise and observe:

a. The shape of each of the semilunar valves.

b. The small knot-like projection on the edge of each valve. What is its function? Try to close the valve and you will see.

10. Find the cut end of the **aorta.** If it is not short enough so that you can see the semilunar valves from above, cut off pieces until you can see these valves.
    a. Pour water into the aorta and observe how the semilunar valves close.
    b. Look for two openings, the **coronary arteries,** just above the semilunar valves. Insert a broom straw into one of these arteries and trace it. What is its function?

11. Remove the upper portion of the **left auricle.** How does its inner surface compare with that of the right auricle? Notice:
    a. The pulmonary veins. How many are there? Do they open near each other?
    b. The **mitral valves** from above. These valves close the left **auriculo ventricular aperture.**

12. Gently pour water into the left auricle. What becomes of the first water poured in? Continue to pour and notice the change in position of the valves. When the ventricle and a portion of the auricle are filled with water what is the position of the mitral valves? Pour out the water and again fill the heart but this time hold the cup one or two feet above the auricle and pour rapidly. How do the valves

close? Make a drawing showing the valves as seen from above.

13. Make an oblique cut across the left ventricle similar to the one made in the right ventricle. Observe:
    a. The number of papillary muscles.
    b. The attachment of the chordæ tendineæ.
    c. The thickness of the wall of the left ventricle as compared with that of the right.
    d. The opening into the aorta as seen from inside the ventricle.

14. Cut through the partition between the two halves of the heart, the **septum**, and notice its thickness, also that there is no direct opening between the right and left sides of the heart.

ARTERIES, VEINS AND CAPILLARIES.

GENERAL DISTRIBUTION. The arteries and veins can best be traced in a mammal whose blood vessels have been injected, preferably the veins with one color and the arteries with another, but the larger vessels may be seen fairly well in an animal that has been killed without bleeding. Directions, apparatus and materials for injecting will be found in the appendix. A cat, rabit, dog or even a rat will answer for this purpose.

2. Open the animal along the middle line of the abdomen and chest, pin back the cut edges and notice the portion of the aorta in the chest, **thoracic aorta.**
    a. How many branches does it give off just

after leaving the heart?

b. Observe the branches going to each fore limb, the **right** and **left subclavian arteries.**

c. The two branches running along each side of the windpipe and continuing along the sides of the head, the **right** and **left carotid arteries.**

3. Observe the branch of the aorta which extends into the abdominal cavity and note the following subdivisions:

a. Small branches going to the stomach, liver, spleen and mesentery.

b. The divisions passing to the kidneys, **renal arteries.**

c. A small branch which supplies the lower portion of the intestine.

d. The final division of the abdominal aorta into two branches, the **common iliac.** These supply the hind limbs.

4. Locate the **pulmonary artery** which leads from the right ventricle to the lungs.

5. Construct a diagram to show the chief divisions of the arterial system.

6. Observe the two large veins leading to the right auricle, the **vena cava ascending** and **vena cava descending.** Also notice the following tributaries of the descending vena cava.

a. The **jugular veins** on each side of the neck.

b. The **right** and **left subclavian veins** which lead from each of the fore limbs.

7. Observe the following tributaries of the ascending vena cava:
   a. The **portal vein,** which gathers blood from the intestine, stomach, spleen and pancreas and carries it to the liver.
   b. The very short **hepatic veins** which gather the blood from the liver and pour it into the vena cava.
   c. The two **iliac veins** that come from the hind limbs.
8. Observe the **pulmonary veins**, which lead from the lungs to the heart.
9. Construct a diagram showing the chief veins, similar to the one called for under arteries.
1. MINUTE STRUCTURE. Cut cross sections of a piece of the aorta of a cow that has been hardened in 2 per cent. potassium bichromate for ten days, stain in picro carmine and mount in glycerine. Observe the three coats which make up its walls:
   a. An **inner coat** lined with a layer of flat cells and composed chiefly of yellow elastic tissue.
   b. A **middle coat** made up of yellow elastic tissue and unstriped muscular tissue.
   c. An outer layer of white fibrous connective tissue with a small amount of yellow fibrous and muscular tissue.
   d. Why is so much yellow elastic tissue present?

2. Make sections of the walls of a vein and examine one in the same way as the artery. Observe the three coats but notice that those in the vein are much thinner than the ones in the artery.
3. If possible examine sections of tissue from an animal whose capillaries have been injected, either with colored gelatine or with silver nitrate solution, the latter to stain but not to fill the capillaries.

THE CIRCULATION.

1. Make a hole one inch in diamater near the end of a shingle or other thin board and over the hole fasten one of the common glass slips used with the microscope. Shape the board so that it will rest on the stage of the microscope with the hole over the aperture in the stage. Trim the board so that it will be just large enough to support the body of a frog when the leg is extended. Select an active frog, wrap around it a damp cloth but leave one leg exposed. With strings tie the wrapped frog to the board in such a position that the web of the exposed foot will just come on the glass slip over the hole in the board. Tie threads to the various toes and with these stretch the web on the glass slip. Place the frog's foot under the microscope and observe:
   a. Large vessels, supplied with blood from still larger vessels, in which the currents are moving swiftly and apparently towards the body, the **arteries**. The direction of the

flow is only apparent since the microscope inverts the image.

b. Large vessels, supplied with blood from still smaller vessels, in which the blood does not move so swiftly as in the arteries, the **veins.**

c. The numerous small vessels, **capillaries.**

d. The **oval blood corpuscles** which move quite freely, and the **white corpuscles** that appear to adhere to the walls, more or less. Do the red corpuscles ever need to change their shapes in order to pass through the capillaries? With a pin slightly irritate the web of the frog's foot and observe that the white corpuscles collect in large numbers at the point of irritation. This is a simple illustration of inflamation.

2. Kill a frog in the manner described on page 51, pin out the feet on a board then make a slit along the middle line of the abdomen and chest and pin back the flaps. Wash away any blood that may have accumulated, find the heart and observe its beat. Note the time of contraction of the two auricles, the time of contraction of the single ventricle. Feel of the heart as it is about to contract and note its rigidity. Observe the heart's **systole**, **diastole** and **pause.**

3. Find the **pulse** in your wrist and in as many other places on the body as possible, especially

about the head. Count the number of pulse beats to the minute under the following conditions:

a. After you have been quiet for some time.
b. After running quickly up a flight of stairs or after other active exercise.
c. Just after awakening in the morning.
d. Before and after a meal.

4. Place your ear to the chest of a fellow student and listen for the sounds of the heart. Observe these sounds carefully. If they cannot be heard readily a simple stethoscope may be made for the purpose by connecting a small glass funnel with a short piece of rubber tubing to a glass U tube. To the arms of the U tube attach longer pieces of rubber tubing. Pieces of curved glass tubing may be connected with the two free ends of rubber tubing for ear pieces. With the two ends in the ears place the funnel over the heart and listen. The thinner the clothing between the chest and the funnel the better will the sounds be heard. If a U tube is not at hand a single tube from the funnel to one ear will answer. A tin funnel may be used if more convenient.

5. To show the action of the heart prepare the apparatus illustrated by figure 2. A, B, C, D are glass tubes tied into the vena cava, aorta, pulmonary artery and pulmonary vein. The ends of the tubes have been enlarged so that they will not slip out. All other openings in the heart should be tied. E, F, G, H are rubber tubes which connect the heart with the funnels, I,

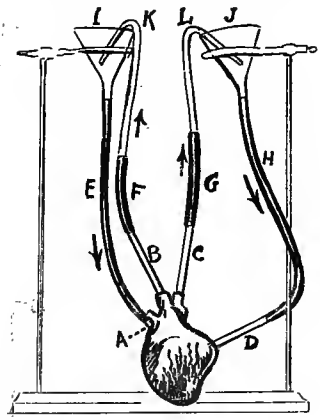

FIG. 2.

J. K, L are two bent glass tubes which hang on the rims of the funnels I, J. Pour water into I and compress the heart with both hands and continue to pour in water until the whole apparatus is filled. Gently compress the heart with the hands then release it, thus imitating as nearly as possible the action of the heart in life, and there will be a circulation of the water through the tubes similar to that of the blood through the blood vessels in life.

Figure 3, illustrates a piece of apparatus which may be easily constructed to show why the blood does not flow intermittently in the veins, also arterial pressure. A and B are two tin cylinders, each 5 inches in diameter and 27 inches high. At the base of each cylinder are two small tubes, F, P, for the attachment of rubber tub-

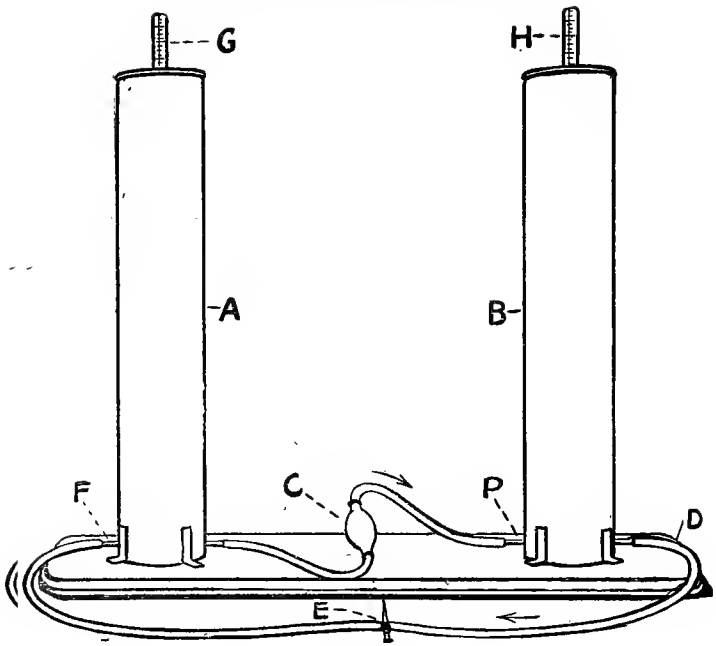

FIG. 3.

ing. The cylinders are screwed to a base and are connected by the tubing and bulb C, also by the tube D. At E there is a clamp which may be changed to regulate the resistance. G, H are the upright parts of two floating gauges which are made of cork and wood. A large cork is placed on the end of each of the upright pieces. The pump is an ordinary syringe bulb.

For the experiment the cylinders are partially filled with water, eight or ten inches deep, care being taken that the rubber tubing also fills without air.

Remove the clamp E and then slowly compress the bulb and notice the effect upon the floats G, H. When the bulb is compressed the water which it contains is thrown into B. While the hand is still on the bulb no water can come into it from A, consequently the float in B must be lifted a short distance. This is only temporary, provided the long tube has a diameter equal to or greater than that connected with the bulb, for the extra water in B soon runs back into A and the floats stand at the same height. Narrow the diameter of the long tube with the pinch-cock E and again operate the bulb. It will be noticed now that it takes much longer for the two floats to gain their equilibrium on account of the slowness with which the water passes through the tube at E. Continue the pumping now for some time and notice that the float H continues to rise higher and higher, but after a few moments it stops. Why? When the bulb was operated, say once in two seconds, the water had time to gain its equilibrium before the next beat, consequently the floats remained at the same mark, except the temporary disturbance. When operated once a second the water did not have time to gain its equilibrium before the next beat, consequently the float in B stood a little higher and that in A a little lower. The variation grows greater but not indefinitely. As the water rises in B the pressure is increased by the force of gravity and this pressure continues to increase. The greater the pressure the greater the volume of water that can be forced through a given orifice in a given time, hence a point is soon reached at which the quantity of

water forced out through the tube D is just equal to the amount forced in from the bulb. The floats now remain stationary. If the bulb is now operated twice as fast, the float in B will again rise, thus increasing the pressure and forcing more water out through the tube D in a given time.

The conditions under which the heart and other blood vessels act are not very different from those represented by this apparatus. The bulb corresponds to the heart, the cylinder B and the end of the tube D attached to it, the arteries, the stop-cock E to the capillaries and the cylinder A and the end of the tube D attached to it, the veins. When the ventricles contract, they throw blood into the arteries and, should the contractions be slow enough, the blood would gain equilibrium and the pressure would be the same in both veins and arteries. This is not the case, however, for more blood is thrown into the arteries than can immediately run through the capillaries into the veins, consequently the pressure is increased in the arteries and that in the veins slightly decreased. These conditions will continue, the pressure increasing in the arteries, until finally a point will be reached at which the pressure in the arteries is sufficient to force just as much blood through the capillaries as is thrown in by the heart in a given time. The pressure becomes so constant that the stream through the capillaries is continuous and there is no pulse in the veins.

The apparatus may be varied and yet show the same principle. Instead of the cyclinders use glass tubing to represent the veins and elastic rubber tub-

ing for the arteries. The capillaries may be represented by using a piece of glass tubing into which a sponge has been placed. The pressure in this latter apparatus will need to be shown by connecting with each tube a glass U tube filled with mercury. The arterial pressure may also be shown by using an elastic rubber bag to represent the arteries and when the water is pumped into this it will expand. The last apparatus described is more complicated than the first and is no more satisfactory.

RESPIRATORY TISSUES AND RESPIRATION.

RESPIRATORY TISSUES.

1a. The organs of respiration and their structure. 2, 193; **3**, 380; **10**, 503; **6**, 202; **5**, 105; **24**, 297, 303; **17**. 341; **14**, 120; **13**, I, 180; 11, II, 554; 12, 433; **25**, 202.

1b. The air passages. **2**, 194; **6**, 203.

1c. The trachea.

1d. Structure.

2c. Bronchial tubes and their branches.

3c. Alveoli.

2b. The lungs. **2**, 196; **6**, 208; **14**, 127.

1c. Structure.

2c. Extent of surface. **2**, 197.

3c. The pleura. **2**, 197.

1d. Pleurisy. **2**, 198.

3b. Thorax or chest. **2**, 200; **3**, 386; **13**, I, 201, 203.

1c. Structure.

1d. Chief muscles of. **10**, 513; **15**, 372; **13**, I, 200.

2c. Directions in which it can expand. **2**, 200.

RESPIRATION.

1a. By what mechanism produced? **2**, 204; **6**, 211; **15**, 370; **13**, I, 198; **12**, 438; **25**, 208.

2a. Inspiration.

3a. Expiration.

4a. Sounds produced in respiration. **2**, 203; **5**, 121; **24**, 317; **13**, I, 206.

5a. Capacity of the lungs. **2**, 199; **3**, 391; **6**, 210; **24**, 318; **13**, I, 191; **25**, 211.

1b. Tidal air.

2b. Complemental air.

3b. Residual air.

4b. Total capacity.

6a. Amount of air breathed daily. **2**, 199.

7a. Effect of respiration on the circulation. **3**, 394; **10**, 555; **24**, 319.

8a. Chemistry of respiration. **2**, 207; **3**, 389; **10**, 517; **6**, 215; **12**, 449; **25**, 215.

1b. Changes that have occurred in breathed air. **2**, 208; **6**, 216; **11**, II, 379; **25**, 217.

1c. In temperature.

2c. In moisture.

3c. In gases. **24**, 321.

1d. Chemical composition of. **17**, 367.

1e. Pure air.

2e. Breathed air. **3**, 400; **6**, 220; **15**, 381; **13**, I, 210, 215; **11**, II, 379.

2d. Quantity of air breathed. **15**, 378.

4c. Changes in the blood. **11**, II, 382; **12**, 451; **25**, 223.

1d. Oxygen taken up by the blood. **24**, 327; **25**, 224.

1e. By what process possible?

2d. Carbon dioxide given off. **25**, 229.

9a. Nervous control of respiration. **2**, 205; **3**, 414-426; **10**, 563; **6**, 213; **24**, 353-362; **17**, 360;

15, 393; **14**, 145; **11**, II, 615; **12**, 475; **25**, 231.

10a. Special respiratory movements. **15**, 406; **17**, 353; **10**, 561; **6**, 218; **12**, 507.

11a. Artificial respiration. **10**, 553; **13**, I, 229; **6**, 393.

12a. Hygiene of respiration. **3**, 392; **5**, 120; **25**, 206.

1b. In reference to clothing.

2b. Ventilation. **31**; **34**; **35**; **2**, 213; **10**, 547; **6**, 223; **13**, I, 231; **25**, 213.

1c. Amount of air needed. Why? **2**, 212.

2c. Poisons in breathed air.

1d. Is carbon dioxide poisonous?

3c. Best methods of ventilating.

3b. Asphyxia. **6**, 381; **24**, 350.

4b. Consumption. **6**, 222.

1c. Cause. **13**, I, 231.

2c. How best guard against?

5b. Effect of tobacco on air passages. **6**, 232.

LABORATORY EXERCISES.

THE AIR PASSAGES AND THE LUNGS.

MATERIALS. Get from a butcher the heart and lungs of a calf, sheep or hog, having directed that no cuts be made on either. The heart is not necessary but if cut off the lungs are liable to be injured. Have ready small pieces of the trachea of a cat or other small mammal that have been hardened in .2 per cent. chromic acid for 10-14 days and then alcohol (see appendix for methods of hardening). Lung tissue har-

dened in chromic acid, the air spaces themselves having been filled with the fluid.

1. Examine the windpipe or **trachea** and notice its rings. Do they continue all around the tube or are they thinner next to the œsophagus? Feel of the rings and determine their structure. Remove one of the upper rings, trim away the surrounding tissues and make a drawing of the ring.
2. Trace the trachea to where it branches into the right and left **bronchial tubes.** Are the branches similar to the main tube?
3. Blow up the lungs in the same manner as described on page 87 and notice:
   a. The **lobes** of the lungs.
   b. The covering or **pleura.** In some places this membrane may be pushed away from the lungs by the pressure of the air.
4. Dissect out one of the bronchial tubes and a few of its branches as far as you can. What finally becomes of these tubes?
5. Cut cross sections of the hardened trachea and observe:
   a. The inner mucous coat covered with **ciliated** cells. Compare these with what you saw in the frog.
   b. Beneath the mucous coat the **submucous.**
   c. Joining the submucous coat the incomplete **ring of hyaline cartilage.**

d. The outer **fibrous coat** in which is imbedded the ring of cartilage.

6. Cut longitudinal sections of the trachea, stain in hæmatoxylin and compare them with the last.

7. Cut sections of hardened lung, stain in the same manner as the trachea and observe the **alveoli** as seen in section, as well as the smaller air tubes. If a piece of an injected lung be used the blood vessels may also be distinguished.

8. Review experiment 16, page 68.

9. Take a deep breath and determine in how many directions the chest may expand.

RESPIRATION.

MATERIALS. A thermometer; a few six ounce wide mouthed bottles; glass tubing; a half gallon fruit jar; the apparatus shown in figure 4.

1. Breath on the bulb of the thermometer and notice:
   a. The film which coats the bulb. What is it?
   b. The effect on the mercury in the thermometer.

2. Breathe on the window pane, the polished blade of a knife or other smooth surface and notice the moisture that condenses.

3. Polish a piece of glass then breathe on it several times. Allow the glass to dry then examine to see if a film has been formed on it. What can this film be?

4. Exhale several times through a tube into a clean bottle then cork up the bottle and stand it in a warm place for a day. After this time open the bottle and ascertain whether or not any odor is given off from the bottle. What explanation?
5. Repeat experiment 14, page 11 with the lime water. Review experiment 13 on page 11.
6. Review experiment 8c on page 86.

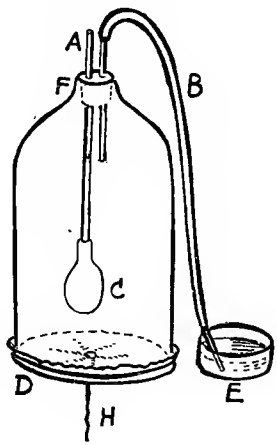

FIG. 4.

7. Make the apparatus shown in figure 4 from a bell jar with a hole in the top, or if such a jar is not at hand a large bottle whose bottom has been cut off will answer. A is a glass tube passing through a rubber cork at F, to the lower end of which is fastened a toy rubber baloon C. B is a tube opening on the inside

of the jar at one end and the other end under the water in the dish E. D is a rubber disc tied to the base of the jar and to the center of which is fastened a string. The cork at F and the rubber disc D must be so placed that they will admit no air. Pull down on the string H and notice the effect on the baloon C. Why does it expand? Notice also the effect on the water in E. Why? The latter illustrates why the blood rushes more rapidly into the chest cavity during an inspiration than at other times. D illustrates roughly the action of the diaphragm in the body. If the toy baloon can not be had the lungs of some small mammal such as a rat may be used for C.

8. A harmless but very instructive experiment may be made by putting a mouse or sparrow into a half gallon fruit jar the lid of which has two glass tubes cemented into it. One of the tubes should be short but the other should reach to the bottom of the jar or nearly so. Close the jar then exhale through the long tube for some time until the mouse begins to become drowsy. Now allow fresh air to flow into the jar. What effect? If an oxygen tank is handy let a little pure oxygen into the jar. Effect? Artificial carbon dioxide may be used instead of breathing into the jar but care must be taken not to allow the experiment to go too far. What conclusions are to be drawn from the experiment?

EXCRETORY TISSUES.

EXCRETORY TISSUES.

1a. Organs concerned in. **2**, 215; **6**, 235; **25**, 385.
1b. Urinary organs.
1c. Kidneys.
1d. Location.
2d. Shape.
3d. Structure. **24**, 393; **12**, 511.
1e. Gross structure. **2**, 217; **3**, 429; **5**, 161; **6**, 257; **17**, 421; **14**, 230; **13**, I, 479.
1f. As seen on the exterior.
1g. Covering.
2g. The ureter.
3g. Renal blood vessels. **24**, 397; **13**, I, 484.
2f. As seen in longitudinal section. **3**, 429.
1g. The hilus.
2g. Pelvis of the ureter.
3g. Calices. **3**, 429.
4g. Cortical portion.
5g. Medullary portion.
6g. Pyramids of Malpighi.
7g. Papillæ.
8g. Pyramids of Ferrein.
2e. Minute structure. **2**, 218; **3**, 429; **5**, 163; **10**, 189; **11**, II, 665; **12**, 514; **14**, 232; **13**, I, 481.
1f. Uriniferous tubules. **13**, I, 482.

1g. Malpighian capsules. **12**, 516.
2g. Trace the tubules.
3g. Physiology of. **3**, 435.
2f. Blood capillaries. **10**, 195.
1g. Distribution. Why?
4d. The urine. **2**, 219; **3**, 432; **10**, 190; **17**, 426; **11**, II, 687; **15**, 426; **12**, 528; **14**, 237; **13**, I, 487.
1e, Amount.
2e. Specific gravity. **13**, I, 488.
3e. Composition. **3**, 433; **17**, 431; **11**, II, 679; **24**, 398; **15**, 422; **12**, 524; **14**, 237; **13**, I, 490.
5d. General physiology of. **3**, 435.
6d. Nervous connection with. **3**, 439; **17**, 439, **24**, 428; **13**, I, 531.
2c. Urinary bladder and ureters. **14**, 243; **13**, I, 538.
1d. Structure.
2d. Physiology of.
3c. Hygiene of.
1d. Importance of healthy kidneys.
2d. Common diseases of. **14**, 242.
1e. Causes.
3d. Effect of stimulants on. **6**, 261-262.
2b. The skin. **2**, 220; **5**, 151; **6**, 237; **11**, II, 719; **24**, 378; **12**, 551; **14**, 244; **13**, I, 543.
1c. Of what consist?
1d. Epidermis or cuticle. **2**, 220; **6**, 238; **24**, 380.
1e. Structure of.
2e. Pigment in. **5**, 152.
2d. Dermis. **2**, 222.

1e. Other names for.
2e. Structure.
1f. Connective tissue.
2f. Blood vessels. **24**, 386.
3f. Lymphatics. **24**, 386.
4f. Pipillæ. **2**, 223; **5**, 153.
5f. Nerve fibers.
3d. Hairs. **3**, 444; **6**, 239; **24**, 381; **12**, 557; **14**, 246; **13**, I, 547.
1e. Structure.
1f. Parts of.
2e. Object of.
3e. Hygiene of.
1f. Gray hairs, dandruff, bald heads.
4d. Nails. **2**, 225; **3**, 445; **6**, 241; **24**, 380; **14**, 246; **13**, I, 546.
1e. Structure.
1f. Parts of.
2e. Object of.
3e. Hygiene of. **6**, 252.
5d. Glands of the skin. **2**, 226; **13**, I, 550.
1e. Sweat glands. **2**, 226; **3**, 446; **5**, 154; **6**, 242; **11**, II, 723; **24**, 385; **12**, 555; **14**, 248.
1f. Location.
2f. Structure.
3f. Secretion. **10**, 198; **24**, 388; **12**, 416.
1g. Composition. **5**, 156; **6**, 243; **14**, 249.
2g. Amount of. **11**, II, 728; **12**, 559; **14**, 249.

3g. Object of.
1h. To regulate temperature. **5**, 157; **6**, 244.
2h. To remove wastes,
4g. Nervous control of. **5**, 155; **3**, 447; **14**, 250; **13**, I, 554.
2e. Sebaceous or oil glands. **2**, 227; **3**, 448; **5**, 156; **10**, 197; **11**, II, 724; **24**, 384; **12**, 556; **14**, 248.
1f. Location.
2f. Secretion. **24**, 391.
1g. Object of.
2c. Absorbing power of the skin. **6**, 246.
3c. Protective function of. **15**, 413; **13**, I, 551.
4c. Respiration through the skin. **12**, 461; **15**, 415; **13**, I, 551; **24**, 392.
5c. Hygiene of the skin, **2**, 228; **3**, 448; **6**, 247.
1d. Bathing.
1e. Kinds of baths and the purpose of each.
2d. Clothing. **6**, 223.
3d. Effect of sunshine. **5**, 161.

LABORATORY EXERCISES.

THE KIDNEYS.

MATERIALS. Get from the butcher some kidneys from any animal, taking care to have the tissues immediately surrounding these organs preserved with them. Harden slices of a small mammalian kidney, such as that of a rat, in Perenyi's fluid or alcohol, also pieces

of bladder in the same manner but the latter organ should be distended with the hardening fluid.

1. GROSS STRUCTURE. Review your drawings made for observation 12, page 67.
2. Observe the capsule of peritoneum which surrounds the kidney.
3. Notice the shape of the kidney, especially an indentation on one edge, the **hilum**. Observe the following tubes which connect with the kidney at the hilum:
   a. The **ureter**, the tube which carries the urine from the kidney to the bladder.
   b. The **renal artery** which supplies the kidney with blood.
   c. The **renal vein** which carries the blood from the kidney.
4. Observe the color of the kidney.
5. Remove the capsule then split the kidney open carefully along the convex edge, cutting deep enough to reach the cavity, the **pelvis**, where the ureter begins. With a broom straw or other small body probe into the pelvis and trace the ureter.
6. Cut the kidney completely open then observe the following:
   a. The color of the membrane lining the pelvis.
   b. The **outer** or **corticle** portion of the kidney.
   c. The **inner** or **medullary** portion which appears somewhat striated.

d. Observe in the mudullary portion the **pyramids** of **Malpighi** which project as **papillæ** into the pelvis. Can you detect a small hole in the end of each pyramid? Press on the kidney while looking to see if any water oozes out.

7. Make a careful drawing of one half of the kidney.

8. Make a transverse cut across one of the halves of the kidney and observe the cut end. Draw.

1. MINUTE STRUCTURE. Make longitudinal sections of the hardened kidney mentioned under materials, stain with hæmatoxylin and observe under low power the cortex, pyramids, Malpighian capsules and tubules.

2. Under high power observe the tubules more closely and try to verify the fact that each Malpighian capsule is the starting point of one of the uriniferous tubules.

3. If sections from a kidney whose blood vessels have been injected with colored gelatine can be had, examine one for the blood capillaries. The capillary network found in the Malpighian capsules is known as the **glomerulus.**

4. Make cross sections of the wall of the bladder, stain with hæmatoxylin and observe the following:

a. Externally, an **outer fibrous coat.**

b. A **muscular coat** whose fibers run in many directions. What is the function of the muscles?

c. A **submucous coat** on which lies the inner **mucuous coat**, the latter folded and lined with epithelial cells.

THE SKIN.

1. Observe the skin which may be rolled off of the body when taking a bath. What portion of the skin is it?
2. Examine the hardened portion of the skin on the inside of the hands or feet. Do these parts bleed when a thin slice is shaved off? Is there any pain when such cutting is done? Why? Where on the body is the epidermis thickest? Where thin? Under what conditions will the epidermis become much thicker than usual?
3. Polish a piece of glass then press the tip of a finger on it. What kind of a print is made? Try other fingers. Examine the palm of the hand for similar ridges, the **papillæ**.
4. Harden a piece of the skin of some animal, preferably human skin if it can be had, by any of the methods mentioned in the appendix, cut sections and observe the following:
   a. The **epidermis**, composed of many layers of flattened cells on the surface and thicker cells beneath. If the section be from the human skin the elevated papillæ may be seen, especially if it be from the palm of the hand or the inner surface of the finger.
   b. The **dermis** or **cutis** beneath the epidermis and composed of connective tissue.

c. In the dermis numerous glands which may be either sweat or sebaceous glands.

5. Review experiments 7, 9 and 10, pages 17 and 18, on hairs.

6. Make sections of a piece of skin which contains hairs, stain with hæmatoxylin and observe the hair follicles and the sectioned hairs. Note the oil glands, the papillæ from which the hairs grow, the fibrous sheathes which line the follicle and the epidermis which covers the root and forms the hair when mature.

NERVE TISSUES.

NERVE TISSUES.

1a. Why need a nervous system? **2**, 230.

2a. How do we differ from a collection of organs? **2**, 231.

3a. What is coordination? **2**, 231; **12**, 790; **11**, III, 1082.

4a. Structure of the nervous system. **13**, II, 648; **29**, 149; **26**, 123; **37**; **17**, 522; **19**; **39**; **40**; **14**.

1b. Nerve trunks. **2**, 232; **3**, 158; **25**, 410; **14**.

1c. What and where found?

2c. Central portion. **3**, 158,

3c. Distal portion, **3**, 158.

4c. Structure.

1d. Covering.

2d. Nerve fibers. **3**, 176; **6**, 265; **14**.

1e. White fibers. **2**, 244; **25**, 433.

1f. Primitive sheath,

2f, Medullary sheath.

3f. Axis cylinder.

4f. Nodes.

5f. Nuclei.

2e. Gray fibers. **2**, 245; **3**, 178.

1f. How like and different from white fibers?

2f. Where found?

2b. Nerve centers. **2**, 234; **3**, 159, 181; **25**, 410; **14**.

1c. What are they?
2c. Cerebro-spinal center. **3**, 160.
1d. Brain. **2**, 234, 238; **5**, 253; **6**, 268; **12**, 731; **11**, III, 1009, 1024; **25**, 417; **19**; **15**, 498; **14**.
1e. Membranes covering. **6**, 273; **25**, 412; **18**, 704; **19**.
1f. Locate and describe each.
2e. Main divisions.
1f. Fore-brain. **3**, 166.
1g. Cerebrum. **6**, 270; **18**, 716; **19**; **24**, 517; **14**.
1h. Location.
2h. Size as compared with the other parts of the brain.
3h. Hemispheres.
4h. Convolutions. **25**, 418.
5h. Olfactory lobes.
6h. Structure.
1i. Gross.
2i. Minute. **13**, II, 849; **11**, III, 1103; **18**, 744; **19**; **24**, 489; **14**.
7h. Function, in general.
2g. Other parts.
2f. Mid-brain.
1g. Location.
2g. Structures on the dorsal side. **3**, 167.
3f. Hind-brain.
1g. Cerebellum. **6**, 271; **18**, 747; **19**; **24**, 514; **14**.
1h. Location.

2h. Lobes of.
3h. Size.
4h. Structure.
1i. Gross.
2i. Minute. **11**, III, 1097; **18**, 751; **19**; **24**, 489; **14**.
5h. Function, in general.
2g. Pons Varolii. **18**, 714; **19**; **24**, 508; **14**.
1h. Location.
3g. Medulla. **6**, 273; **12**, 736; **11**, III, 1009; **18**, 708; **19**; **24**, 503; **14**.
1h. Location.
3e. Ventricles of the brain. **3**, 168; **25**, 422; **18**, 753; **19**.
1f. Locate and describe each.
4e. The brain as seen in section. **3**, 170.
1f. Corpus callosum.
2f. Septum lucidum.
3f. Optic thalami.
4f. Optic commissure.
5f. Pituitary body.
1g. Theories concerning.
6f. Pineal body.
1g. Theories concerning.
7f. Inner view of the cerebellum.
8f. Other common structures not mentioned above.
5e. Blood vessels of the brain. **5**, 263; **12**, 881; **11**, III, 1235; **14**.
6e. Weight of the brain. **3**, 166; **10**, 715; **25**, 417; **24**, 541.

7e. Cranial nerves. **2**, 240; **3**, 172, 207; **5**, 258; **6**, 275; **13**, II, 717; **25**, 425; **18**, 754; **19**; **24**, 545; **14**.

1f. Name, locate and state function of each pair.

8e. Growth of the brain, **2**, 260; **10**, 715, 724; **36**.

2d. Spinal cord. **2**, 235; **3**, 161, 181; **6**, 277; **12**, 671; **11**, III, 915; **25**, 414; **18**, 695; **19**; **37**; **24**, 495; **15**, 480; **14**.

1e. Location.

2e. Diameter and length.

3e. Enlargements.

4e. Weight. **10**, 723.

5e. Coverings.

6e. Gross structure. **3**, 162; **12**, 675; **14**.

1f. White and gray matter.

2f. Fissures.

3f. Central canal.

7e. Minute structure. **3**, 181; **24**, 486; **14**.

1f. Arrangement of the white fibers.

2f. Arrangement of the gray fibers.

3f. Arrangement of the nerve cells. **2**, 245; **10**, 607.

1g. Minute structure. **3**, 179; **6**, 264; **25**, 431; **14**.

2g. Function. **17**, 541.

3g. Nutrition. **10**, 626.

4f. The neuroglia. **3**, 180; **25**, 439.

3c. Spinal ganglia and nerves. **6**, 278; **13**, II, 751; **25**, 415; **18**, 789; **19**; **24**, 545; **14**.

1d. Location.

2d. Number of pairs of nerves.
1e. How joined to the cord?
3d. Structure and connections of the ganglia. **3**, 184.
1e. Sympathetic system. **2**, 243; **3**, 175; **6**, 286; **13**, II, 756; **24**, 559; **14**.
4c. Sporadic ganglia. **3**, 176.
1d. Location.
2d. Probable function.
5a. General physiology of. **38**; **40**.
1b. Properties of nervous tissue. **3**, 180.
2b. Location of feeling and pain.
3b. What is a sensation? **5**, 267, 269.
4b. Nature of nervous impulse. **2**, 247; **3**, 203; **25**, 443.
1c. Rate of transmission of . **3**, 206.
2c. Compare with electricity.
5b. Nerve action. **2**, 248, 258.
1c. Motor stimuli.
1d. Relation to the anterior roots of the spinal nerves. **17**, 545.
2c. Sensory stimuli.
1d. Relation to the posterior roots of the spinal nerves. **17**, 546.
3c. Location in the spinal cord of the motor nerve cells.
4c. Location in the spinal cord of the sensory nerve cells.
5c. Where are the voluntary motor centers?
1d. Explain voluntary movements. **12**, 808; **11**, III, 1119.
6c. Classification of nerve centers. **25**, 447.
1d. Reflex (see special physiology). **3**, 188.

2d. Conscious centers. **3**, 189.
3d. Automatic centers. **3**, 189.
4d. Relay and junction centers. **3**, 189.
7c. Inter communication of nerve centers. **3**, 207.
8c. Classification of nerve fibers. **3**, 193; **25**, 445.
1d. Peripheral.
1e. Afferent. **2**, 252; **17**, 524.
1f. Define.
2f. Sensory, reflex, excito-motor, inhibitory.
2e. Efferent. **2**, 252; **17**, 525.
1f. Define.
2f. Motor, vaso-motor, secretory, trophic, inhibitory.
2d. Intercentral.
1e. Exciting, inhibitory. **3**, 190.
9c. Nerve stimuli. **13**, II, 658; **25**, 440; **17**, 527.
1d. General. **3**, 195.
1e. Define, illustrate and state kinds.
2d. Special. **3**, 196.
1e. Define, illustrate and state kinds.
10c. Explain "specific nerve energies" and show that all nerves are physiologically alike. **3**, 197; **25**, 441.
11c. Degeneration of nerve fibers. **3**, 209; **25**, 438.
6a. Special physiology of. **38**; **40**; **14**.
1b. Of nerve centers, in general. **3**, 294.
2b. Of the spinal cord. **2**, 254; **13**, II, 764.
1c. As a conducting organ. **3**, 594; **6**, 279, 280; **15**, 487.

2c. As a reflex center. **2**, 252; **3**, 600; **6**, 28; **12**, 711; **15**, 484.
1d. Illustrated by experiments on a frog.
3c. Its connection with the spinal ganglia.
4c. Physiological explanation of reflex action. **10**, 657.
5c. Time required for reflex movements. **3**, 608.
6c. How acquire reflex movements?
7c. Value of reflex action. **2**, 259; **6**, 284.
8c. Education of reflex centers. **3**, 605.
9c. Does the spinal cord think or feel? **3**, 607.
1d. Proof of your answer.

3b. The brain. **3**, 609; **15**, 505; **14**.
1c. General function.
1d. The seat of consciousness.
2d. Effect of removing the cerebrum from birds. **12**, 784; **13**, II, 844; **11**, III, 1072; **15**, 500.
2c. The medulla oblongate. **2**, 255; **3**, 610; **5**, 263; **13**, II, 806; **25**, 445; **15**, 542.
1d. Minute structure. **12**, 799.
2d. Special function.
1e. As a connection between the brain and spinal cord.
2e. Seat of relay and junction centers.
3e. Reflex and automatic centers.
4e. Function of the nerves that arise here.
3c, Cerebellum, and pons Varolii. **2**, 258; **3**, 613; **14**.
1d. Special function. **5**, 263; **25**, 457; **15**, 541.

1e. Effect of removing the cerebellum from birds. **13**, II, 897.

2e. Function in maintaining equilibrium. **3**, 614.

4c. Mid-brain. **3**, 616; **13**, II, 885; **25**, 459; **14**.

1d. Function.

5c. Fore-brain (cerebrum). **3**, 618.

1d. Brain localization. **2**, 257; **10**, 682, 696; **13**, II, 875; **11**, III, 1119; **25**, 229, 433; **15**, 521, 530.

1e. Function of the cortex. **2**, 256; **3**, 622; **5**, 259.

2e. Nerve connections in the cerebrum. **10**, 647, 668; **12**, 748; **15**, 518.

3e. Locate some of the known motor aries.

1f. Illustrate by aphasia. **3**, 628.

6c. The brain as a reflex center. **6**, 284.

7c. Mental habits. **2**, 260; **3**, 631.

1d. Explanation.

7a. What is the explanation of old age? **10**, 742.

8a. Comparative physiology of the nervous system. **10**, 703.

9a. Development of the nervous system. **24**, 477; **15**, 542.

10a. Hygiene of. **2**, 261; **6**, 288.

1b. Need of rest. **6**, 288.

2b. Sleep. **6**, 290; **10**, 739; **25**, 465.

1c. What is it?

2c. Why necessary?

3c. Amount required.

3b. Effect of stimulants on the nervous system. **16**, 294; **5**, 274.

4b. Causes of apoplexy and paralysis.
5b. Hypnotism. **25**, 467.

LABORATORY EXERCISES.

NERVE TISSUES.

MATERIALS. A fresh sheep's head, which may be obtained from the butcher; two frogs; a saw; four per cent. formalin solution; pieces of the brain and spinal cord hardened in formalin; carmine stains and acetic acid.

1. THE BRAIN. With a fine saw make cuts along each side of the sheep's head, across the face and across the base of the skull, and with a file or other strong object pry off the top of the skull. The cutting must be done with care in order that the brain may not be injured. As the top of the skull is removed observe:
   a, The tough membrane which lines it, the **dura mater.**
   b. That the surface of the dura mater has a glossy appearance on account of being covered with the very thin **arachnoid membrane.**
   c. The membrane covering the brain, the **pia mater.** This contains blood vessels and its surface is covered with the arachnoid membrane.
2. Place the head for a day in a jar which contains a solution of 4 per cent. formalin. The solution will harden the brain and then it can be more easily removed. After hardening, lift

the brain very gently and cut off the nerves as near the skull as possible, taking care not to tear them off where they join the brain.

3. Observe the following parts of the brain:
   a. The large **cerebrum** which constitutes the main portion of the brain and which is divided into two **hemispheres**.
   b. The **cerebellum**, back and somewhat beneath the cerebrum. Notice its surface.
   c. The **medulla**, below the cerebellum.
   d. On the under side of the cerebrum, the **olfactory lobes**.
   e. Back of the olfactory lobes, the **optic commissure**, from which the optic nerves pass forwards and the optic tracts backwards.
   f. The **pons Varolii**.
   g. The stumps of the **cranial nerves**.
4. Trim away a portion of the pia mater and observe the **convolutions** on the cerebrum. Pull the two hemispheres apart and observe the white portion which connects them, the **corpus callosum**.
5. If a hardened brain is not at hand it would be better to put the brain in a fresh 4 per cent. formalin solution for from four to five days until it has hardened more completely, then make a horizontal cut across one hemisphere of the cerebrum and notice:
   a. The **gray matter** which covers the surface of the brain.

b. The depth of the convolutions.

6. If the cut has been made through the middle of the cerebral hemisphere some of the ventricles should be seen.

7. Make a vertical cut through the cerebellum and notice the nature of its interior. What is its color? Draw.

*8. Stain a small piece of the hardened cortex of the cerebrum for 24 hours or longer in borax carmine, transfer directly to 100 cubic centimeters of 70 per cent. alcohol to which has been added five drops of strong hydrochloric acid and allow it to remain in the acid alcohol for 24 hours. The material may now be dehydrated, imbedded in paraffin and cut. Examine for the many small nerve cells. Material hardened in formalin may be imbedded and sectioned before staining, and the sections may be stained on the slide for a few moments in a weak solution of iodine green in water. Wash in water and mount in glycerine for temporary observation. With the latter stain, the nerve processes are fairly well shown.

9. Prepare sections of the cerebellum in the same manner as directed for the cerebrum and observe:

a. The outer layer.

b. The large **nerve cells** of **Purkinje**

*) There are very many excellent methods of demonstrating the minute structure of the nervous system but they are nearly all too complicated for the beginner. It is thought that the few directions here given will answer fairly well but those who care to go more into details should consult any of the standard text-books on histology (see 40 of the reference list.)

under the outer layer and with many nerve processes.

c. Beneath the nerve cell layer a **granular layer**.

10. If there are any preserved brains of other mammals, birds or other animals in the laboratory they should be studied and compared with the one just mentioned. Models of the human brain should be carefully studied.

1. THE SPINAL CORD. Make a cross section of the hardened spinal cord from near the neck of some mammal by either the paraffin or the celloidin method, stain in borax carmine and observe the following:

a. The outer coverings of the cord. How many coats are shown?

b. The **anterior** and **posterior median fissures**. Which one dips down to the gray matter?

c. The H shaped gray matter with its **anterior** and **posterior horns** and nerve processes extending to the surface of the cord.

d. The **multipolar nerve cells** in the anterior horns of the gray matter.

e. The **gray fibers**, the fibers which make up the greater portion of the gray matter.

f. The **central canal** in the middle of the cord.

g. The ends of the nerve fibers in the white portion of the cord.

2. If it is possible to have sections of the lower portion of the cord, compare those with the ones from the upper portion.
3. Cut pieces, about one fourth of an inch in diameter of the anterior horn of the spinal cord, from the neck of a cow, place it in borax carmine and allow it to remain for two or three days. Wash away the stain with water and then add glycerine. Tease the colored mass apart and mount a portion. Examine for nerve cells. Excellent preparations may be obtained by this method. Glycerine jelly is good for making permanent mounts.
4. Remove a short piece of the sciatic nerve from the leg of a frog, put it on a dry glass slip, press one end down so that it will adhere to the slip and with a needle fray the nerve out as fine as possible, then apply a drop of normal salt solution and observe:
   a. The size of the nerve fibers.
   b. The second or **medullary sheath** which is apt to be somewhat wrinkled.
   c. In places where the medullary sheath is broken, the outer, transparent **primitive sheath.**
5. If there is some osmic acid in the laboratory take another piece of fresh nerve and place it in a 1 per cent. solution of the acid, where it should remain for several hours. Tease on a slide in water or glycerine and observe:
   a. That the medullary sheath is stained black.

b. The numerous **nodes** of **Ranvier** at which the **axis cylinder** may be seen passing from one internode to another.

1. NERVOUS SYSTEM OF A FROG. Place a frog in a jar with a little ether and let it remain until dead. Open the animal along the abomen and remove the viscera. Observe along each side of the spinal column a row of white bodies, the **ganglia,** also the nerves which go to the hind limbs.

2. With sharp scissors remove the top of the skull, observe the brain and note:

a. In front, the rather large **olfactory lobes.**

b. Just back of the olfactory lobes the **cerebral hemispheres.**

c. Following the cerebral hemispheres, two rounded bodies, the **mid-brain.**

d. The small **cerebellum** just back of the mid-brain.

e. The **medulla.**

1. REFLEX ACTION. With a wire destroy the brain of a frog then close the hole made by the wire with a wooden plug, so that there will not be a loss of blood. Allow the frog to remain quiet for a few minutes until it has recovered from the shock of the operation then perform the following experiments:

a. Compare the posture of a live frog with that of one whose brain is destroyed.

b. Pinch a toe of the hind foot. What happens?

c. Pinch the skin on the side of the body. Does the frog attempt to scratch off the irritating object?

d. Touch the frog's side with strong acetic acid or vinegar and observe the result. How explain?

e. Try a hot wire in the same way that you did the acid.

f. Touch the toe with the two wires from a weak induction coil.

2. Run a wire down the spinal column and destroy the spinal cord then repeat the experiments just indicated. How explain the result?

1. General experiments. Find the sciatic nerves of the frog, which go to its hind legs. Pinch one. Effect? How explain?

2. Why does a person wink when struck at, even if he knows that the person striking will not hit him?

3. Tickle the inside of the nose and what happens? Explain.

4. When we hit the elbow why do we sometimes feel pain in the fingers?

SPECIAL SENSES AND THE VOICE.

SPECIAL SENSES.

1a. In general. **3**, 488; **25**, 469; **17**, 566; **24**, 562; **15**, 548.

2a. Sensations. **2**, 263; **3**, 488; **6**, 307; **5**, 284.

1b. General or common. **3**, 490.

2b. Special.

1c. Sight.

1d. The eye. **2**, 265; **3**, 504; **6**, 321; **5**, 301; **25**, 529; **10**, 744; **11**, IV, 1-173; **14**, 343; **17**, 586; **24**, 579; **15**, 560; **12**; **41**, 96.

1e. Accessory parts.

1f. Eyesocket.

2f. Eyelid. **3**, 506; **2**, 266; **25**, 542; **13**, II, 974; **24**, 598.

1g. Eyelashes.

2g. Glands on the edge of the lid.

3g. Muscles.

4g. Object of winking.

5g. Conjunctiva. **5**, 301.

3f. Eyebrows. **25**, 541.

4f. Lachrymal apparatus. **2**, 267; **3**, 507; **6**, 334; **25**, 543; **13**, II, 974.

1g. Function.

2g. What becomes of the secretion?

3g. Physiology of weeping.

5f. Muscles of the eyeballs. **3**, 505; **6**,

332; **25**, 544; **10**, 745; **13**, II, 962; **14**, 369.
2e. Optical apparatus. **3**, 325.
1f. In general.
1g. Nature of light. **3**, 516; **25**, 531, **41**, 115.
1h. Kinds of rays.
2g. Lenses.
1h. Refraction. **3**, 520; **25**, 538.
2h. Formation of images.
2f. Eyeball.
1g. Coats. **3**, 509; **25**, 546; **11**, IV, 21; **14**, 345; **12**.
1h. Sclerotic.
1i. Structure and function of.
2h. Cornea. **13**, II, 906.
1i. Structure and nature of. **3**, 509.
3h. Choroid.
1i. Location and structure.
2h. The iris. **17**, 605.
1j. Muscles of.
2j. Color.
3j. Function. **13**, II, 936.
3i. The pupil. **13**, II, 929; **15**, 569; **41**, 111.
1j. Purpose. **5**, 311; **11**, IV, 31; **12**.
4h. Retina. **2**, 270; **5**, 305; **10**, 773; **13**, II, 912; **14**, 351; **24**, 586.
1i. Location.
2i. Structure. **25**, 550; **11**, IV, 55.
1j. Function of the rods and

cones. **10**, 787; **14**, 357.
3i. Connection with the optic nerve.
4i. The yellow spot or area of acute vision. **3**, 511; **5**, 306; **13**, II, 947.
5i. Physiology of.
2g. Refracting media. **2**, 274; **3**, 515; **6**, 328; **14**, 358.
1h. Cornea.
2h. Aqueous humor.
3h. Crystalline lens, **24**, 593.
1i. Location.
2i. Structure. **13**, II, 916.
3i. Physiology of.
1j. How change shape? **3**, 516; **25**, 548, 560; **10**, 752.
4h. Vitreous humor. **3**, 516; **13**, II, 917.
1i. Location and purpose.
3g. Optic nerve. **25**, 549; **14**, 360; **41**, 109.
1h. Where enter the eye?
2h. The blind spot. **3**, 532; **2**, 272; **5**, 210; **41**, 149.
3h. Visual center in the brain.
4g. Blood vessels of the eye. **14**, 362; **24**, 594.
1h. Where enter and how distributed?
3e. Comparative anatomy and embryology. **13**, II, 976; **15**, 597.
4e. Compare the eye with a photographic camera. **3**, 521; **13**, II, 919.
1f. How are images formed on the ratina?

13, II, 923; **24**, 608.

1g. Accommodation of the lens. **3**, 522; **5**, 308; **13**, II, 926; **11**, IV, 13; **14**, 599; **15**, 565; **12**; **41**, 137.

2g. Why inverted?

3g. Why do we not see things inverted?

5e. Defects in the eye. **3**, 525; **6**, 329; **25**, 553; **10**, 759; **13**, II, 931; **11**, IV, 47; **24**, 616; **15**, 572; **12**; **41**, 131.

1f. Near-sightedness.

1g. Cause and remedy.

2f. Far-sightedness.

1g. Cause and remedy.

3f. Why must old people wear glasses? **3**, 526.

4f. Irregularity in curvature. **3**, 528.

1g. Astigmatism. **2**, 276.

1h. Remedy.

5f. Opaque bodies in the refracting media. **3**, 528.

6e. Effect of light on the retina. **3**, 530-534; **10**, 776; **13**, II, 937; **14**, 613; **24**, 627.

1f. Physiology of vision purple. **3**, 535; **13**, II, 915; **11**, IV, 115; **12**.

2f. Other theories.

3f. Duration of luminous sensations. **3**, 539; **5**, 312:

4f. Localizing power of the retina.

1g. Importance.

5f. Color vision. **5**, 311; **25**, 568; **10**, 781; **13**, II. 952; **11** IV 84; **14**

377; **24**, 634; **15**, 583; **12**; **41**, 158.

1g. Young's theory. **3**, 542; **25**, 571; **13**, II, 955.

2g. Herring's theory. **3**, 548; **25**, 575; **13**, II, 936.

3g. Color blindness. **3**, 545; **6**, 336; **5**, 311; **25**, 568; **13**, II, 957.

7e. Visual perceptions. **3**, 552; **10**, 796; **13**, II, 972; **11**, IV, 155; **24**, 644; **12**.

1f. Of distance.

2f. Of size.

3f. Of solids.

4f. Why see objects singly when looking with both eyes? **3**, 553; **25**, 580; **10**, 801; **14**, 375; **24**, 640; **41**, 170.

8e. Hygiene of the eyes. **2**, 277; **6**, 336; **5**, 312.

1f. Location of the light while reading.

2f. When glasses should be recommended.

1g. Importance of testing the eyes of school children.

3f. Effect of cold on the eyes.

4f. General directions for the use of the eyes.

2c. Hearing. **5**, 316; **17**, 628; **41**, 200.

1d. The ear. **2**, 279; **3**, 557; **6**, 343; **25**, 494, 507; **10**, 807; **13**, II, 978; **11**, IV, 176-244; **14**, 383; **24**, 659; **15**, 604; **12**.

1e. External ear.

1f. The concha.

2f. Auditory meatus.

2e. Middle ear or tympanum. **13**, 557; **14**, 387.

1f. The tympanic membrane or drum. **10**, 809.
2f. Eustachian tube.
1g. Function.
3f. Bones of the ear. **14**, 388.
1g. Names, shapes and arrangement.
2g. Function.
3e. Internal ear. **3**, 559; **14**, 390; **41**, 223.
1f. Of what consist?
1g. The bony labyrinth. **3**, 560.
1h. Vestibule.
1i. Location and description.
1j. Otoliths.
2h. Semicircular canals.
1i. Their ampulæ.
3h. Cochlea.
1i. General anatomy. **10**, 819.
2g. Membranous labyrinth. **3**, 561.
1h. In the vestibule.
1i. Divisions and their description.
2h. In the semicircular canals.
1i. Ending of the auditory nerve. **14**, 395.
2h. In the cochlea.
1i. Parts and their arrangement.
2i. Organ of Corti or nerve end-endings. **3**, 562.
4e. Nature of sound. **3**, 564; **2**, 282; **25**, 494; **10**, 825; **14**, 400; **24**, 680; **41**, 277.
1f. Meaning of the terms loudness, pitch and timber.
2f. Sympathetic vibrations. **3**, 569.
5e. Physiology of the ear. **3**, 571; **10**, 832.

1f. Of the tympanic membrane. **3**, 571.
2f. Of the ear bones.
3f. Of the cochlea.
1g. Different views.
4f. Of the semicircular canals. **2**, 282; **3**, 574; **24**, 694.
6e. Comparative study. **15**, 617.
7e. How determine direction and distance?
8e. Hygiene of the ear. **6**, 349; **5**, 318.
3c. Touch. **2**, 283; **3**, 576; **6**, 310; **5**, 286; **25**, 477; **10**, 834; **13**, II, 1013; **14**, 327; **17**, 569; **24**, 647; **15**, 555; **41**, 41.
1d. Special nerve endings for. **3**, 576.
1e. Tactile cells. **3**, 576.
2e. End bulbs.
3e. Tactile corpuscles. **41**, 45.
1f. Location.
4e. Pacinian corpuscles.
1f. Location and function.
2d. What is touch? **3**, 578; **41**, 52.
3d. Localization of skin sensations. **2**, 284; **3**, 580; **25**, 482.
1f. Illustrations.
4c. Temperature sense. **3**, 582; **5**, 290; **25**, 484; **13**, II, 1022; **11**, IV, 278; **14**, 336; **17**, 576; **15**, 554; **12**.
1d. Explanation.
2d. Compare with touch.
3d. Function of this sense.
5c. Smell. **2**, 286; **3**, 587; **5**, 298; **10**, 849; **13**, II, 1004, **11**, IV, 250; **14**, 340, 581; **24**, 573, **15**, 620; **12**; **41**, 81.
1d. Nerve endings in the nose.

2d. Explain just how we smell.
3d. Function of this sense.

6c. Taste. **2**, 286; **3**, 589; **6**, 313; **5**, 296; **25**, 488; **10**, 851; **13**, II, 1009; **11**, II, 246; **14**, 581; **24**, 570; **15**, 623; **12**; **41**, 70.
1d. Taste buds and their location (p. 56).
2d. What kinds of substances can be tasted?
3d. Function of this sense?
4d. Hygiene of.

7c. Muscular sense. **2**, 285; **3**, 591; **6**, 312; 5, 292; **25**, 486; **10**, 844, **13**, II, 1026; **11**, IV, 295; **14**, 334; **15**, 557; **12**; **41**, 68.

THE VOICE.

1a. Organs immediately concerned in. **2**, 289; **6**, 356; **5**, 321; **11**, IV, 306.
1b. The larynx. **3**, 634; **25**, 239; **10**, 861; **11**, IV, 312; **13**, II. 633. **24**, 705; **14**, 260; **17**, 512.
1c. Location.
2c. Structure.
1d. The cartilages.
2d. Vocal cords. **6**, 358.
1e. Location.
2e. Structure and nature of.
3d. Muscles.
1e. How act?

2a. Nature of and just how produced. **3**, 633; **2**, 288; **6**, 359; **13**, II, 640, 647; **24**, 711; **14**, 264; **17**, 517.
1b. The vowels.
2b. Consonants.
1c. Classification. **3**, 643.
3b. Range of the human voice.

3a. Hygiene of the vocal cords. **6**, 364.

LABORATORY EXERCISES.

THE EYE.

MATERIALS. Get from a butcher either the head of some mammal which still has the eyes uninjured, or some eyes that have been carefully removed. Have ready the eyes of a small mammal that have been hardened by soaking in Perenyi's fluid for 24 hours, then 80 per cent alcohol, with several changes of the latter, and finally preserved in 80 per cent. alcohol. Get an assortment of skeins of colored worsted from the store or from a dealer in kindergarten supplies; a test card for eyes from James W. Queen & Co., Philadelphia; a photographic camera; a tube three-fourths of an inch in diameter, 10 inches long and black on the inside; a prism; a rotating apparatus; and an electric machine.

1. STRUCTURE. Examine an eye that has been carefully removed from its socket, preferably after its position was noted, and observe the four muscles which pass backward towards the back of the socket, and the two oblique ones which serve to roll the eye. Make a drawing to show these muscles.
2. Notice the following on the outside of the eyeball:
   a. The cut end of the **optic nerve.**
   b. The nature of the **sclerotic coat.**
   c. The transparent **cornea.**
3. Look through the cornea and observe:

a. The **iris**. What is its color?
b. The **pupil**, formed by the iris.

4. With sharp scissors cut across the cornea and notice that a liquid, the **aqueous humor**, escapes. Note the thickness of the cornea.
5. Trim away the cornea and examine the iris. Slit it with the scissors, lift up one edge and see if it is of the same color on the inside as on the out.
6. Remove the iris and observe beneath it the **crystalline lens**. Notice how it is fastened around its edge. Remove the lens without injury and put it on a printed page. Examine the letters through the lens. Effect?
7. Cut the lens. Of what consistency? Is it elastic?
8. Trim away a little more of the front of the eye and notice the jelly-like **vitreous humor**. Pour it out carefully and observe:
   a. The whitish, delicate membrane which lines the back portion of the eye, the **retina**.
   b. The brownish or black **choroid coat**, which lines the front of the eyeball and passes back under the retina. Observe the blood vessels in it.
   c. The place where the optic nerve enters.
   d. ~~If the retina is in place, the "yellow spot" or area of acute vision.~~
9. Notice the thickness of the sclerotic coat, also its toughness. Does it seem to help preserve the shape of the eyeball as well as to protect it?
10. Imbed in celloidin an eye hardened according

to directions given under materials, but before doing so a hole should be cut in one side of the ball and the vitreous humor carefully removed without injuring the retina (see appendix for celloidin imbedding.)

11. Cut horizontal sections of the eye, stain in borax carmine or hæmatoxylin and eosin, mount and observe how the cornea is joined to the sclerotic coat. Observe the following structure of the cornea:
    a. The outer **epithelial layer**, just under which is a narrow **elastic layer.**
    b. The main body of the cornea which is full of **corneal corpuscles**, whose edges show.
    c. The thin **inner layer.**
12. In the same section examine the part where the iris branches off and notice:
    a. The **ciliary muscles** which control the crystalline lens.
    b. The structure of the iris.
    c. The structure of the choroid coat.
    d. The fastening of the crystalline lens and the structure of the lens itself.
13. If a fresh lens be soaked in a solution of 5 drops of sulphuric acid to 5 cubic centimeters of water for 24 hours, then washed in water and stained in borax carmine, it may be teased apart so that the fibers of the lens will show nicely.
14. Examine the retina in the section used above and note the **rods** and **cones** near the choroid coat. This section will likely be too thick for

the observation of all the elements of the retina. If it is desired to study the retina more in detail, imbed in paraffin a portion of an eye which contains the retina then cut thin sections. These sections may be stained in hæmatoxylin, and eosin. For other methods see **30**, page 365.

1. EXPERIMENTS. Focus a photographic camera that has a ground glass back and notice how the image is inverted. Draw a diagram in your note-book to show how this inversion takes place.
2. Take a fresh eye of some animal and, if it is one with a thick coat, trim off a portion of the back of the eye and place the trimmed off portion over the end of the tube mentioned under materials. With your eye at the other end of the tube, notice that an inverted image is formed on the retina similar to the one in the camera.
3. If the lens of the camera is fitted with an iris diaphragm or different sized diaphragms, try the largest and then the smallest and notice the effect on the light. Compare with the iris in the eye.
4. Look at the black board or some other black object for a few minutes than quickly into a mirror and observe the size of the pupil. Look out of the window or at a bright light then observe again the size of the pupil. What inference?
5. With a prism separate the rays of sunlight into the various colors. If the laboratory is

supplied with a rotating apparatus and discs, an attempt should be made to combine the various colors by rotation, Try the primary colors, dark and light colors.

6. If there is any apparatus for producing an electric spark, a revolving black and white disc should be observed in a dark room by the aid of the sparks. The black and white spaces should be seen distinctly when viewed by the sparks but the disc appears gray as it revolves in ordinary light. How does the experiment illustrate the duration of luminous sensations?

7. Those who are known not to be color blind should test the other members of the class for color blindness. Have ready a number of skeins of various colors of worsted. Pick out a pale green one and ask the person who is being tested to pick out all the other skeins that are of the same, or nearly the same, color. If he picks out some that are quite different he is likely color blind. Do not mention the names of the colors to the person who is being tested.

8. Take a skein of medium purple and go through the same process.

9. Make the same test, using a light red skein of medium shade. By these three tests it is easy to determine whether or not a person is color blind.

10. Hold your book at the distance from the eye at which the print is read with the least effort. What do you find this distance to be? If it is much less than 12 inches you are near sighted.

If much more than 15 inches, you are far sighted. Children can see objects nearer the eyes than grown persons.

11. Hold your finger 12 or 15 inches in front of you in a vertical position then look at some object across the room. Why does the finger appear double? Why is it indistinct? Reverse the operation by looking at the finger and then noticing the effect on the object across the room.

12. Make in your note book, three or four inches apart, two squares whose sides are one inch in length. Across one, draw horizontal lines at equal distances apart. Across the other, make similar vertical lines. How do the two squares now appear? This illustrates imperfect, visual judgment.

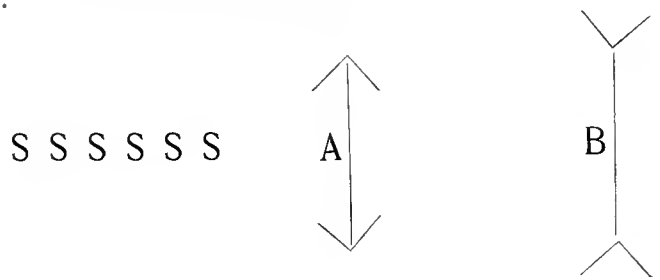

FIG. 5.

13. Observe the letter S in figure 5. How do the upper and lower ends compare in size? Invert the letters and what is the result? Measure the two lines, A and B. Why do they not appear of the same length?

14. Hold a pencil in a vertical position, about 6 inches in front of the face, then look at it with both eyes. Close the left eye and place a finger in a vertical position so that it seems to cover one end of the pencil. Try to strike the pencil with the finger. You will likely miss. Why?

FIG. 6.

15. Close the left eye and look at the letter A with the right. While doing so, move the book back and forth until a point is reached where B is not visible. Rays from it now fall on the blind spot of the eye.

16. Obtain one of Queen's test cards, hang it where there is good light then make the following tests:

    a. Try to read the letters under number 1 at a distance of 20 feet. Do you have any difficult in recognizing any of them? If you do, walk nearer until they can all be seen.

    b. Stand 20 feet from the card and look at the black lines in number 2. Do they all appear of the same blackness and are all distinct? If not, which ones are indistinct? This test is for **astigmatism** or unequal curvature of the eye. Eyes that are badly astigmatic cause headaches and other disorders.

c. Find the distance from the face at which the letters in number 3 can be read. How near can you see them? How far away?

If your eyes are found seriously defective by any of the above tests, and you have not done so, you should consult an oculist. Should the test card here recommended not be at hand, any other such card may be used and the teacher can give directions for the experiments.

THE EAR.

MATERIALS. Head of a fish; model of an ear; a rabbit or cat's head; a large tuning fork; steel bars; a small watch.

1. Examine a good model of the ear and locate all of its chief parts.
2. If a pickerel's head (*Esox lucius*) can be had, the student should carefully dissect out the semicircular canals of the ear. The head of any fish in which the bones are soft will answer. The portion of a mammal's skull which contains the ear may be softened by soaking in weak acid, and then the essential parts of the ear may be dissected out.
3. Cut out the ear portion from the skull of a rabbit or cat, that has just been killed, place it in Perenyi's fluid until decalcified, transfer it to 80 per cent. alcohol for a day, change the alcohol once or twice, then 70 per cent. alcohol and finally borax carmine. After staining, wash in acid alcohol, dehydrate, imbed in paraffin and cut sections vertical to the coils of

the cochlea. Mount and notice the turns of the cochlea. If desired, the minute structure of the cochlea may be studied.

4. Set a large tuning fork in vibration and notice its pitch. If a small bar of steel is at hand, hit it with a mallet and notice its pitch. Try a much smaller piece. You will find one whose pitch is so high that your ear cannot detect its tones.

5. Blindfold a person and test his sense of direction by making sounds in different directions about him. Try with both ears open then with first one and then the other closed.

6. With a watch, the teacher should test a few members of the class to see if their sense of hearing is perfect, then a few such students should test the other members of the class. Test each ear separately and let each student record the distance at which he can hear the ticking distinctly. Try a tuning fork instead of a watch. Many persons are partially deaf but have not discovered it.

7. Close the ears then see if you can hear a watch tick. Place the watch between the teeth. What effect? How explain?

TASTE AND SMELL.

MATERIALS. Sugar; salt; quinine; potato; apple; roasted coffee; perfumes; onions; oils that give off odors.

1. Wipe the tongue dry and then place on its tip a few crystals of sugar. Are they tasted immediately; If not why? Try sugar on differ-

ent parts of the tongue. Where is it best tasted?

2. Make a solution of quinine in water. Touch the tongue on the tip with a very small drop of the solution. Is it readily tasted? Try the back portion of the tongue in the same manner. Where is the quinine tasted best?
3. Try salt in the same manner as sugar. Where is it best tasted?
4. Blindfold a person, have him hold his nose then put small pieces of potato and apple on his tongue, at different times, and see if he can tell which is which.
5. Chew some roasted coffee, first with the nose closed and then open. What difference is noticed?
6. Try different substances that have odor, using different strengths, and determine how far away they can be detected and how much more sensitive some noses are than others. Perfumes, onions, coffee and various oils will answer for this experiment.

TOUCH AND TEMPERATURE.

MATERIALS. Forceps; test tubes; hot water; pieces of wire; some fur.

1. With a pair of forceps that have blunt points, touch the skin of a blindfolded person in different places and determine for each place how far apart the points may be and still be felt as one. Try the tips of the fingers, tip of the tongue, palm of the hand, face, back of the neck and the arm. Both points must be put down at the same time.

2. Put one hand in water which is 100 degrees F., the water feels warm. Put the same hand now in water at 85 degrees and it feels cold. Why? Put the other hand in water that is 85 degrees and what is the difference in sensation?

3. Blindfold a person and have ready two test tubes, one with hot and the other with cold water. Touch the skin in various places, first with one tube and then the other, and have the person tell which is the hot and which the cold tube. Try the same experiment with the ends of wires, one quite warm and the other cold. Have the blindfolded person touch wool, fur, metal and wood, and report which seems the cooler. Explain why.

THE VOICE.

1. Obtain from the butcher the larynx of a hog or a calf. Examine the epiglottis and notice how it closes over the windpipe. Observe the two flaps, the **vocal cords**, which partially close the upper opening of the windpipe. Notice the cartilages which compose the larynx. Try to dissect them out.

2. Over the end of a tube tie two strips of thin sheet rubber in such a manner that the end of the tube will be all closed except a narrow slit between the two edges of the rubber. With the lungs, force air through the tube and note the sound produced. Try to make the rubber a little tighter and note the difference in sound.

3. Close the nose then speak the word "blinking," after which repeat it with the nose open.

What difference? The cavity in the pharynx serves as a resonator.

4. Speak the letters of the alphabet and notice with each the position of the lips, teeth and tongue. The latter organs help to modify the sounds.

REFERENCE BOOKS.

No special order has been observed in making up the following list.

1. Dictionary, any unabridged.
2. Martin's the Human Body, briefer course. Henry Holt and Co., N. Y. One of the best briefer texts.
3. Martin's the Human Body, advanced course. Henry Holt and Co., N. Y. One of the best books published.
4. Shepard's Chemistry. D. C. Heath and Co., Boston. Any other good Chemistry will answer just as well. Refer to the index.
5. Colton's Practical Physiology. D. C. Heath and Co., Boston. Good for laboratory work. Has some excellent diagrams.
6. Blaisdel's Practical Physiology. Ginn and Co., Boston. Excellent for hygiene.
7. Overton's Applied Physiology. American Book Co., Chicago. Not always reliable.
8. Hutchinson's Physiology. Maynard, Merrill and Co., N. Y. Good for hygiene.
9. Huxley's Physiology, MacMillan Co., N. Y. This old book is still excellent in many respects.
10. American Text-book of Physiology. W. B. Saunders, Phila. The best large American text-book. It is strictly a Physiology.

11. Foster's Physiology, complete, 5 volumes. MacMillan Co., N. Y. One of the best.

12. Foster's Physiology, one volume. Lea Brothers and Co., Phila. An abridged edition of No. **11.**

13. Landois and Stirling's Physiology. English edition, 2 volumes. Charles Griffin and Co., London. Excellent. Finely illustrated.

14. Thornton's Physiology. Longmans, Green and Co., N. Y. An excellent little book.

15. Mills' Animal Physiology. D. Appleton and Co., N. Y. Excellent. Is more or less comparative.

16. Foster and Shore's Physiology. MacMillan Co., N. Y. A good elementary text.

17. Yeo's Manual of Physiology. P. Blakiston, Sons and Co., Phila. An advanced book that has many good points.

18. Gray's Anatomy. Lea Brothers and Co., Phila., Excellent.

19. Quain's Anatomy. Longmans, Green and Co., N. Y. May be had in 9 parts and ranks first as an anatomy.

20. Cyclopedias (Johnson's, American, Brittanica, International).

21. Stewart's Physiology, W. B. Saunders, Phila. An excellent advanced text.

22. Thompson's Zoology. D. Appleton and Co. A good text for reference in comparative work. Any other good Zoology will answer.

23. McKendrick's Text-book of General Physiology. MacMillan Co., N. Y. One of the best general Physiologies.

24. McKendrick's Text-book of Special Physiology. MacMillan Co., N. Y. An excellent advanced book.

25. Rettger's Advanced Studies in Physiology. Inland Publishing Co., Terre Haute, Ind. Covers about the same ground as No. **3**, but the language is simpler.

26. Wiedersheim's Structure of Man. MacMillan Co., N. Y. For comparative anatomy.

27. Prudden's Bacteria. G. Putnam's Sons, N. Y. Excellent for hygiene.

28. Morrison's Ventilating and Warming of School Buildings. D. Appleton and Co., N. Y.

29. Wiedersheim's Comparative Anatomy. MacMillan Co., N. Y. Excellent.

30. Stirling's Histology. P. Blakiston, Sons and Co., Phila. Excellent for methods.

31. Lincoln's Sanitary Conditions of School Houses.

32. Stirling's Practical Physiology. P. Blakiston. Sons and Co., Phila. An excellent book for the laboratory.

33. Foster and Langley's Practical Physiology. MacMillan Co., N. Y. Excellent for directions in dissecting and for histology.

34. Sternberg's Disinfection and Individual Prophylaxis against Infections Diseases.

35. Brodie's Experimental Physiology. Longmans, Green and Co., N. Y. For advanced work.

36. Donaldson's the Growth of the Brain. Scribner, N. Y. Excellent.

37. Horsley's the Brain and Spinal Cord. Charles Griffin, London.

38. Ferrier's the Functions of the Brain. Smith, Elder and Co., London. Excellent.

39. Starr's Brain Surgery. Wm. Wood and Co., N. Y.

40. Sach's Nervous Diseases of Children. Wm. Wood and Co. N. Y.

41. McKendrick and Snodgrass' Physiology of the Senses, Scribner. N. Y.

APPENDIX.

The following apparatus and reagents will be found necessary for successfully carrying out the directions given in the preceding pages. There are many other pieces of apparatus and numerous reagents that might be mentioned, but it is thought that the beginner will do better work if limited to a few of the standard hardening fluids and stains, and to simple methods of preparation. For further details, reference should be made to the standard works on histology.

The reagents and apparatus here mentioned, unless otherwise indicated, may be purchased of the Bausch and Lomb Optical Co., Rochester N. Y., or Chicago, or of any other dealer in microscopical supplies.

DISSECTING.

Good dissecting may be done with a sharp pocket knife, but it is convenient for each student to have a scalpel, a pair of scissors, a pair of forceps and a dissecting needle. Directions for dissecting are found in the text. One or two good razors are necessary for cutting sections and a small saw will be needed frequently.

HARDENING AND PRESERVING FLUIDS.

Alcohol. Alcohol was formerly used for hardening a great many kinds of tissues, but now many

other fluids have taken its place. When used for hardening, fresh tissue should first be placed in 50 per cent. alcohol for from 12 to 24 hours, then be transferred to 70 per cent. for the same time, then to 80 per cent., where it may remain until needed, but the last alcohol should be changed two or three times. Material which is intended for dissection may be placed directly into 70 per cent. alcohol for 24 hours and then transferred to 80 per cent. where it may remain until used. The best alcohol, as it is sold, is usually about 95 per cent. and from this the other strengths may be made by adding water. For histological purposes, absolute alcohol is sometimes used. It is expensive but only small quantities are needed. Ordinary alcohol may be obtained by High Schools and other institutions free of revenue, and, in case any quantity is used, it should be obtained in that manner. As small a quantity as 10 gallons may be so purchased but it is better to get it by the half barrel or barrel. Directions for obtaining alcohol free of revenue may be had by application to the nearest collector of internal revenue.

Formalin. This substance has but recently come into use but it is rapidly displacing alcohol for many purposes, because it is cheaper and material preserved in it is better. As obtained, formalin is a 40 per cent. solution of formaldehyde in water. For preserving purposes a 4 per cent. solution, calling the formalin as obtained 100 per cent., is commonly used. If the material is for histological purposes a 5 or even a 10 per cent. solution is recommended by some. Material hardened in formalin will answer for nearly all purposes for which hardened material

is needed in the preceding exercises.

CHROMIC ACID. This substance has long been a standard hardening reagent. It is used in weak aqueous solutions, ranging from .2 to 1 per cent. Material that is being hardened in chromic acid should be kept in the dark, the liquid should be changed frequently and from 5 to 10 days are required for hardening. After hardening, the material must be thoroughly washed in water for several hours until every trace of acid is removed. Chromic acid material does not always stain readily.

PERENYI'S FLUID. This is an excellent hardening reagent and it is made as follows: 10 per cent. nitric acid 40 parts, .5 per cent. chromic acid 30 parts, and 95 per cent. alcohol 30 parts. Fresh material should be used, and small objects will harden in from 3 to 6 hours, larger objects in from 12 to 24 hours, and, if it is desired to decalcify bones, they may be left in the fluid for several days. After hardening, the material is transferred directly to 80 per cent. alcohol, which should be changed once a day for two or three days. This solution will be found very convenient and satisfactory.

OSMIC ACID. Osmic acid comes in one half or one gram sealed glass tubes and is expensive. A 1 per cent. solution is most frequently used and it is prepared by breaking a 1 gram tube in 100 cubic centimeters of distilled water. The tube must be under water when broken. Weaker solutions are easily made from the 1 per cent. solution. It is an excellent hardening fluid and may be used to advantage where recommended in the preceding exercises.

STAINS.

The beginner will get the best results by limiting himself to a few of the standard stains.

BORAX CARMINE. This stain is usually made by dissolving 1 gram of carmine in a solution of borax, 2 grams to 200 cubic centimeters of water. The whole is heated to boiling and then a few drops of acetic acid are added. After the stain has stood for 24 hours it may be filtered, when it is ready for use. A drop or two of carbolic acid will keep it from spoiling. Material stained in borax carmine should be transferred from the stain to 70 per cent. alcohol, which contains 5 drops of hydrochloric acid to 100 cubic centimeters, where it may remain from 1 to 24 hours according to the size of the object.

PICRO-CARMINE. This stain had better be purchased ready for use. Directions are found for its use in the text. Sections stained with it must not be washed in water. They are most easily mounted directly from the stain in Farrant's solution.

HÆMATOXYLIN AND HÆMALUM. Hæmatoxylin must be made several months before it can be used, hence it is better to purchase it from some reliable dealer. Hæmalum is easily made and answers the same purpose. In fact it is much better for some things. Dissolve 1 gram of hæmatein in 50 cubic centimeters of 90 per cent. alcohol, by heating, and 50 grams of alum in 1000 cubic centimeters of distilled water. Pour the two solutions together. After standing, it may be filtered. These stains are known as the logwood stains and they give excellent results.

EOSIN. This is an aniline stain and is usually used in a 5 per cent. solution. It acts well as a double stain with hæmatoxylin or hæmalum.

SILVER NITRATE. A one fourth to one half per cent. solution is frequently used and it stains intercellular substance. Material to be stained is placed in the solution for from 5 to 10 minutes then it is transferred to water and placed in the light until it turns brown. It is now transferred to alcohol.

MAGENTA. 1 gram of magenta dissolved in 5 cubic centimeters of 95 per cent. alcohol and 15 cubic centimeters of water, with the addition of 20 cubic centimeters of glycerine, makes a good stain for blood corpuscles.

STAINING.

In most cases it will be found best to stain small pieces of material in bulk. This is done after the material has been hardened. Since the stains are generally of an aqueous solution, the substance to be stained must be first transferred from the alcohol; in which it is preserved, to water. Sections cut in celloidin may be easily stained after they are cut, but paraffin sections to be stained must be fastened to the glass slip with a fixative, the paraffin then melted by heat and the slide stood in turpentine or xylol until the paraffin is dissolved. The slide is now placed in absolute alcohol for several minutes, passed through 95, 80 and 70 per cent. alcohol and then to the stain. When the section is stained it is washed, passed back through the alcohols and finally into xylol or turpentine, after which a drop of Canada balsam is added and the cover glass applied. After

staining in the logwood stains the sections are washed in water, but after borax carmine they should be placed in the alcohol mentioned under that stain. Picro-carmine stained sections should be mounted directly in Farrant's solution.

OTHER SOLUTIONS.

IODINE. Dissolve 2 grams of iodide of potassium in 100 cubic centimeters of water then add iodine flakes to saturation. This solution is used in testing for starch.

FEHLING'S SOLUTION. **Solution A.** 103.92 grams of pure crystalline cupric sulphate are dissolved in 500 cubic centimeters of distilled water. **Solution B.** Dissolve 320 grams of Rochelle salts in 500 cubic centimeters of warm water and filter. **Solution C.** Dissolve 150 grams of caustic soda in 500 cubic centimeters of water. Equal parts of the three solutions are poured together when needed for use. The solution is used in testing for grape sugar.

NORMAL SALT SOLUTION. This solution is prepared by adding 6 grams of common salt to 1000 cubic centimeters of distilled water. It is used for diluting blood and for washing out bood vessels.

FARRANT'S SOLUTION. This is used as a mounting medium and only small quantities will be needed. It should be purchased.

IMBEDDING.

It is necessary to imbed nearly all animal tissue before it can be sectioned.

IMBEDDING IN PARAFFIN. Hardened material, either stained or unstained, is transferred from 80 to 95 per cent. alcohol for from 12 to 24 hours, then to

absolute alcohol for several hours, and from this to xylol or cedar oil until it is clear, which will require from 1 to 24 hours, depending on the nature and size of the object. Xylol will generally give better results than cedar oil. The object is now transferred to a pan, which contains melted paraffin, where it should be kept for 2 to 24 hours, depending on the size and nature of the material.

A good but cheap method of keeping the paraffin at the proper temperature is as follows: Have legs about 6 inches long fastened to a piece of sheet copper, which is 4 inches wide at one end, about 12 inches long, and tapering to a point at the other end. A gas or alcohol flame may be kept under the point and a pan containing the paraffin is placed on the table in such a position that the paraffin will just be melted in one half of it and unmelted in the other half. Tin spoons with the handles bent so that they will hang over the sides of the pan, with the spoon level on the bottom, will serve to hold the objects to be imbedded. The paraffin should be neither too soft nor too hard. It is better to have some of different hardnesses, then these can be mixed. When cut, the paraffin should form a perfect ribbon without crumpling or curling.

After the object has remained in the melted paraffin the required time, it should be transferred to some small vessel which contains melted paraffin, where it may remain until cooled. A convenient vessel for this purpose may be made by taking two pieces of lead and bending them in the shape of a letter L. They should be from one half to one inch wide and may be placed on a piece of glass so as to form a box,

into which the paraffin is to be poured. The object should be placed in the box of melted paraffin in the position in which it is to be sectioned.

IMBEDDING IN CELLOIDIN. Celloidin usually comes dry in cakes or shreds. It should be dissolved in a mixture of one half absolute alcohol and one half pure sulphuric ether. Three solutions, thin, medium and thick should be made. Objects to be imbedded are passed from 80 through 95 per cent. and absolute alcohol, the same as for paraffin imbedding, and then into a one half absolute alcohol and ether solution, before being placed in the celloidin. Objects, beginning with the thin, should remain in each celloidin

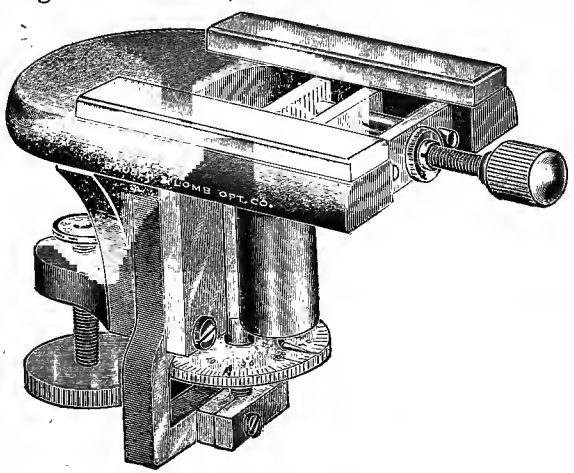

FIG. 7.

solution for 24 hours, after which they may be placed in the proper position on the end of a cork or block of wood and covered with thick celloidin. The

celloidin is allowed to dry on the outside, when the whole is immered in 80 per cent. alcohol. After 24 hours, the celloidin will be ready for sectioning, but it may be kept in the alcohol for any length of time.

SECTIONING.

In order to cut good sections it is necessary to have some kind of a microtome, and, unfortunately, there are not any very satisfactory ones for sale at a very low price. Figure 7 shows a very convenient, simple, hand microtome, which may be had from the

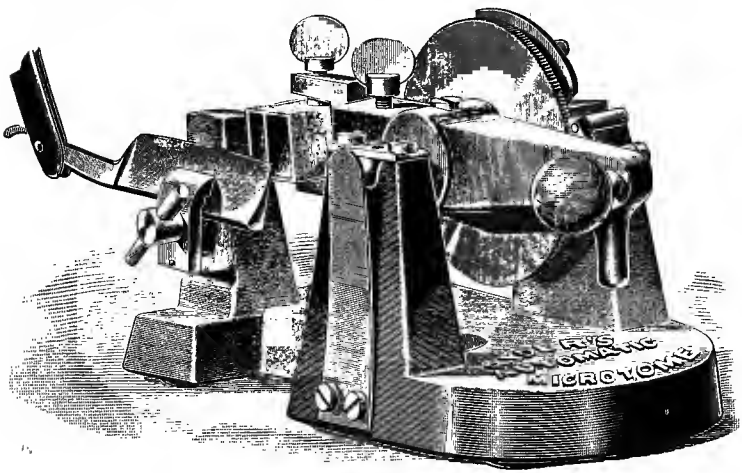

FIG. 8.

Bausch and Lomb Optical Co,, Rochester, N. Y., for about $10. It is an all around microtome and, with a sharp razor and some experience. very good sections may be cut. The imbedded object is fastened in the clamp, and, if it is in paraffin, the block should be

trimmed square. The razor must be brought forward with its edge parallel to the surface of the block. The object is fed up by the screw from beneath. The razor should be kept flat on the microtome. For celloidin, the razor should be drawn across the block at an angle and both it and the celloidin must be kept wet with 80 per cent. alcohol.

Figure 8 shows an excellent automatic microtome which may be had of Joseph Zentmayer, Philadelphia, for about $20. With it, both paraffin and celloidin material may be sectioned, for the razor can be set at any angle, and the sections can be made as thin as desired. Paraffin sections will come from the razor in a ribbon. For more expensive microtomes, the reader is referred to the catalogues of various dealers in microscopical supplies.

MOUNTING.

*Paraffin sections are fixed to the slide by applying a very thin coat of Mayer's albumen fixative. This is made by mixing equal parts of filtered, fresh white of egg and glycerine. Put on a small drop, spread it around then rub off as much as you can with your finger. The section is now pressed down on the slide and then it is heated until the paraffin melts. The slide is then stood in a jar of turpentine or xylol for 4 or 5 minutes, then removed, a drop of Canada balsam added and the cover glass applied. The slide is now ready to be examined, or it may be set aside in a horizontal position until wanted. The balsam will finally dry. Neat wooden boxes for holding 25 slides each may be had of any dealer.

*Directions for staining paraffin sections will be found on page 159.

Celloidin sections may be transferred to water and stained, if the object was not stained before imbedding, they are then washed, passed through the alcohol (dehydrated) to 95 per cent. and from this into oil of bergamot or a mixture of 1 part of pure carbolic acid with 3 parts of xylol, where they should remain until transparent. Xylol is next applied, then Canada balsam and the cover glass.

INJECTING BLOOD VESSELS.

A good injecting syringe is desirable for injecting the blood vessels of an animal, but the injecting mass may be put in some vessel that can be lifted several feet above the animal, and which has a rubber tube leading from it to the canula that is to be inserted into the blood vessel to be injected. For dissecting purposes, a starch injecting mass is most convenient. It is made as follows: 20 parts of powdered starch are thoroughly mixed with 20 parts of water, 5 parts of 95 per cent. alcohol and 10 parts of the color mixture mentioned below, after which the whole is strained through cloth. The color mixture is made by stirring 1 part of any dry color, that will not stain, such as vermillion, red lead, Berlin blue or chrome yellow, with 1 part of 95 per cent. alcohol and 1 part of glycerine. The injecting mass must be thoroughly shaken before it is used.

For histological purposes, a gelatine mass should be used. A carmine mass may be made as follows: Soak 20 grams of good gelatine in cold water for 5 or 6 hours then pour off the extra water and heat the gelatine in a double vessel until it melts. Rub 8 grams of carmine to a paste in a mortar, with water

add 10 cubic centimeters of strong ammonia, mix thoroughly, then add 100 cubic centimeters of water. Pour the color mass into the melted gelatine, stirring briskly. Add acetic acid, a few drops at a time, until the odor of ammonia disappears and the color has changed to a light red. The mass is now filtered through flannel. This mixture must be used warm and the animal should be in warm water. A gelatine mass, ready prepared, may be had of dealers.

An animal to be injected is first etherized, and just as soon as it is dead, the body is opened and a slit is made in the ventricle so that as much blood will escape as possible. It is best to inject warm normal salt solution into the vessels to wash out the remaining blood. When ready for the color mass, the canula, which may be of glass or metal, is inserted through the heart into the aorta or pulmonary artery, tied and the pressure applied. Before removing the canula, tie the vessel that has been injected. A different colored mass may be injected into the two vena cavæ.

PREPARATION OF BONES.

It is desirable to have skeletons and skulls for comparison and these may be prepared by first boiling the bones in a liquid soap solution then washing, scraping and polishing. The soap solution is made by adding 12 grams of saltpeter, 75 grams of hard white soap and 150 cubic centimeters of stronger ammonia to 2000 cubic centimeters of soft water. The soap may first be dissolved in a portion of the water by heating. The bones are cleared of as much flesh as possible then boiled for three fourths of an

hour in a mixture of 1 part of soap solution to 4 parts of water. They are then boiled for half an hour in a mixture of 1 part of soap solution to 1 part of water, when they are immersed in cold water and washed. All surplus flesh should be removed with scalpel and forceps.

ERRATA. Page 69, line 21, for *materials* read, 21, page 68. Page 76, foot note, for *alimintary* read, alimentary. Page 78, line 22, for *Haemaglobin* read, Haemoglobin. Page 143, line 27, for *than* read, then.